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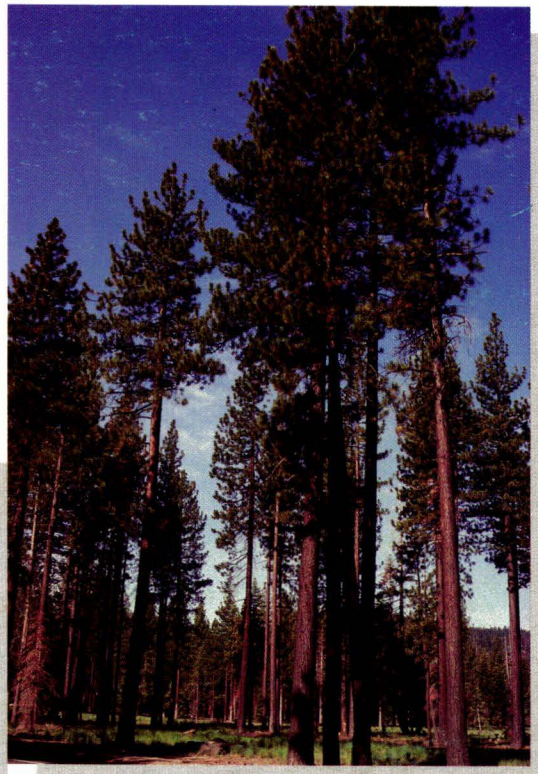
September 1994

California Forest Health

Past and Present



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Cover -- (clockwise from top) Residual stand of Jeffrey pine following removal of dead and dying white fir, Lake Tahoe Basin Management Unit; White fir mortality, east shore, Lake Tahoe Basin Management Unit; washing vehicles and equipment is a valuable tool commonly used to limit the spread of Port-Orford-cedar root disease.

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Pacific Southwest Region

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1 Executive Summary

The desired state of forest health is the condition where biotic and abiotic influences do not threaten resource management objectives and provide desired, sustainable ecosystems. Resource management objectives reflect the many uses and values of the forests in California, including wildlife, timber, recreation, grazing, water and wilderness, and must take into consideration the ecological limitations and processes. The ecological condition of many of the forested acres in California has been altered resulting in an increase in susceptibility to wildfire, insects, pathogens, and weather-induced stresses. Introduced insects and pathogens, and the increasing degree of the urban-wildlands interface throughout the state continue to present forest health concerns. Abiotic factors are also a concern, particularly ozone in the Sierra Nevada and in southern California.

Mortality Above Normal

Over the past few years, many of the forested areas in California have sustained catastrophic losses due to drought and bark beetles. Tree mortality in excess of 80% of the standing volume, has been greatest in overstocked stands and in stands where past harvesting practices and successful fire control and suppression strategies have encouraged the growth of tree species susceptible to insects, pathogens, fire and drought. Although conditions are not uniform across the forests, extensive drought and bark beetle-related mortality has occurred throughout the Sierra Nevada, particularly on the east side from Lake Tahoe north to the Oregon border. Forests in southern and northwestern California are also experiencing higher levels of conifer mortality. Estimates of conifer mortality on National Forest System lands in 1993 identified over 750,000 acres with mortality levels above normal. This included almost 1.5 billion board feet of timber, principally pine and true fir species.

Fuel, Fire Concerns

Compounding these losses are the extreme fire conditions present in many of the ecosystems throughout the state. Altered natural fire regimes resulting from successful fire control and past management practices have combined to alter natural fire regimes. This, along with the high levels of recent mortality, have resulted in increased fuels accumulation. These increased fuels and the extremely dry conditions are causing large, stand-replacing fires in areas that historically experienced small, low-intensity fires.

Biotic Influences

California's conifers and hardwoods are hosts to many native insects, pathogens and animals. Bark and engraver beetles are presently the primary insects that are affecting several host species throughout the state. Defoliator activity in conifers is at low non-damaging levels. Defoliator activity in hardwoods, particularly on several oak species and elm trees, is very common throughout the natural and introduced range of the hosts. Several conifer species are affected by diseases caused by native pathogens, including annosus root disease, black stain root disease and host-specific species of dwarf mistletoe. In localized areas throughout the coniferous forests of the state, root diseases cause tree mortality and predispose their hosts to successful attack by bark beetles. Dwarf mistletoe infection is very common throughout many of California's ecological sections; almost 7 million acres of forested lands are infested. In areas where dwarf mistletoe infection conflicts with resource management goals, control projects are often conducted to limit impacts. The number of acres of trees damaged by animals varies from year to year. Pocket gophers cause the most damage. Protection from animal damage is needed on more than 50,000 acres annually.

Introduced Pests Rise

There are a number of introduced insects and pathogens that have greatly affected their hosts within the state. White pine blister rust, first introduced in 1929 into Siskiyou County, has spread throughout the range of sugar pine in northern California. This pathogen, combined with other agents (drought and bark beetles), is altering the natural species composition of mixed conifer ecosystems in some areas. A pathogen of Port-Orford-cedar is significantly affecting the management of areas in northwestern California where this tree exists. The presence of Dutch elm disease has resulted in the removal of at least 3,502 elms in 11 counties since 1975. Several native and introduced pine species, particularly Monterey pine, are being threatened by the pine pitch

canker fungus. Introduced insects affecting hardwoods are the ash white fly, found in 47 counties and the Eucalyptus longhorned borer, found in 18 counties. Gypsy moth is not established in California, but moths are routinely captured, primarily in populated areas. In 1993, twelve moths were captured from San Diego County to Shasta County.

Ecological Organization

This report is organized based upon the Province and Sections levels of the National Hierarchical Framework of ecological units and covers federal, state and private lands. Fire, weather, animal damage and multiple-agent interactions are covered under "Influences on forest ecosystems." Other disturbance agents are discussed at the province and/or section level depending upon their distribution. Forest health issues in the urban forests follow the ecological unit discussions.■

2 INTRODUCTION

Growing concerns about our environment in general, and our forests in particular, have substantiated the need to focus on assessing the condition of the hardwood and coniferous components of the ecosystems throughout the nation. This report presents information about the historical and current impacts on forest health by the major biotic and abiotic agents with respect to the major ecological types in California.

A Look Back

The existing conditions of the forests in California are the result of many natural forces, exotic organisms, and human disturbances that have altered these ecosystems through time.

Natural agents such as weather, fire, indigenous insects, pathogens and animals have played integral roles in the development of the present condition of the vegetation in California. Weather-related damage, particularly that resulting from wind, drought, or lightning caused fires has frequently had localized and widespread effects on the vegetation. In addition to, and often in interaction with weather-related changes, there are many indigenous insects, pathogens and animals that have coevolved with, and caused changes to, the vegetation. These disturbance agents are generally inconspicuous except during periods when their subsequent damage becomes readily apparent over large areas or when such damage limits attainment of resource management goals. Native insects and pathogens have the potential to greatly affect forested ecosystem processes. These effects do not necessarily indicate a deterioration of an ecosystem. Historically, effects have primarily been considered in relation to their negative impact on timber related resources. It is important to recognize, however, that all insect and pathogen-related effects do not equate to negative resource damage.

Exotic or introduced insects and pathogens are also responsible for altered ecosystems in California. The rich and diverse plant communites found in the state have evolved in relative isolation due to natural barriers: the ocean, mountain ranges and deserts. Most introduced insects and pathogens have been transported into the state by humans or in shipments of plants and livestock. Despite intense quarantine and eradication efforts many exotic organisms have become established, often on introduced hosts, in the absence of their natural predators, parasites and pathogens. Ash whitefly and Eucalyptus long-horned borer are examples of established exotic insects. White pine blister rust, Dutch elm disease, and pitch canker are well established diseases that have dramatically effected their hosts within the state.

Human related disturbances have been significant factors in shaping the forests and woodlands. Pre-Columbian natives affected forests and woodlands through their use of fire to promote the growth of grasses and encourage wildlife. They tended the vegetation in the lands they occupied over thousands of years to create a favorable home environment - to keep the forests more open, encourage higher deer populations, and favor the production of acorns (Dasmann 1981).

The first Spanish settlers in 1769 introduced livestock to the state. Grazing was commonplace throughout the rangelands which were dominated by perennial grasses. The onset of the Gold Rush in 1849 saw a dramatic increase in settlers and livestock coming into the state. As miners and settlers moved into the Central Valley and Sierra Nevada, livestock grazing extended to the valley grasslands and foothills. Periodic droughts resulted in driving the livestock higher into the mountains, and sheep began to dominate the higher mountain grasslands and meadows. It became common practice for livestock herders to set fire to the forest when leaving the high mountain ranges at the end of the summer grazing season in order to improve grazing for the next year. Resource industries other than livestock were also established during the Gold Rush. Demands for timber increased as the mining and construction industries became established. Timber harvests increased from 20 million board feet cut in 1849 to almost 320 million board feet by 1869 (Dasmann 1981).

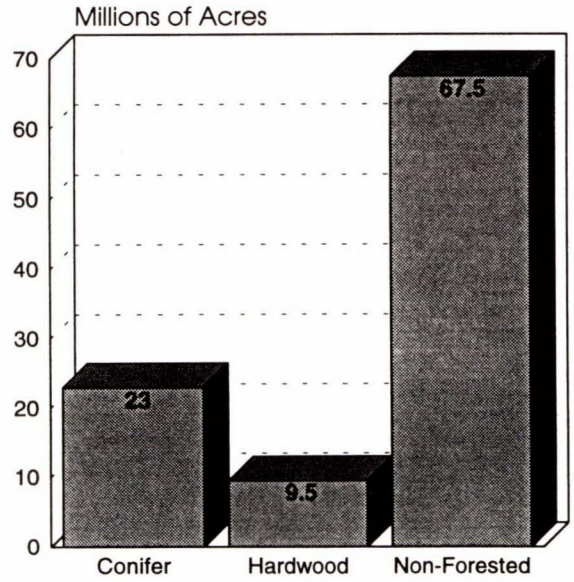
Efforts to regulate forest practices in the state began as early as 1872 when the state legislature made an effort to prevent forest fires with a bill establishing stiff penalties for setting fires on state and federal lands. In 1885 the first state Board of Forestry was created and soon became involved in pressuring the federal government to do something to protect the forests of the public domain. In the early 1890's large areas were set aside throughout the state as National Parks and forest reserves, the latter of which were to become National Forests, and controls were established for grazing, fire, and timber harvest-

ing.

The development of urban centers in the early 1900's led to an increase in timber harvesting and the onset of urban water demands of the forested watersheds. Up until the 1950's, most timber harvesting in the state occurred on private lands (Oswald 1970). But as private stocks began to decline, the Forest Service began selling timber to private companies and providing access roads to many remote areas, leading to increased harvesting on federally-owned lands (Ewing 1988).

The development of California's natural resources set the stage for the tremendous population and economic growth that has taken place in the state. Today, population and economic growth are having profound effects on the use and management of the state's coniferous and hardwood resources. Timber and livestock industries are major suppliers of goods for state and national markets and an important source of employment in rural areas. Water, important to the State's quality of life and several sectors of the economy, originates largely on the forested and alpine watersheds of Northern California. In addition, the forests provide recreational opportunities for millions of annual visitors and support more than 650 species of wildlife (Ewing 1988)

Figure 1-1 - California lands, forested and non-forested. (Source: FRAAP Information and Analysis System)

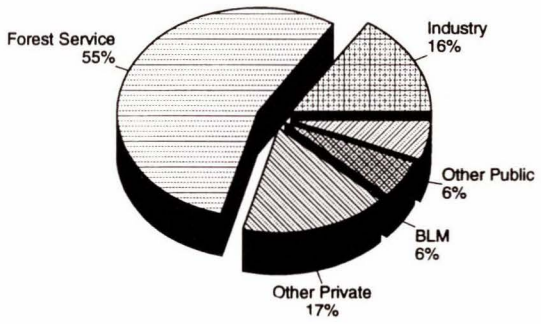


Forest Resources

The Conifer and Hardwood Resources

The Forests in California are unusual in many respects. Not only do they include the world's tallest trees in the coastal redwoods of Humboldt county, the world's biggest trees in volume, the massive giant sequoias of the Southern Sierra, and the world's oldest trees, the bristlecone pines, but also a greater variety of woody plants than is to be found in any region outside of the tropics (Dasmann 1981). There are several native and ornamental conifer species throughout California. In broad-leaved, deciduous trees, California cannot compare with the eastern forests, but it has a great variety of broadleaf trees, including 18 species of oaks.

Figure 1-2 - California Forested Acres by Ownership - - Conifers. (Source: FRAAP Information and Analysis System)

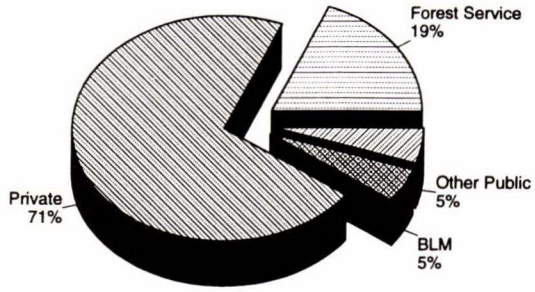


Percent of total (23 million acres)

California is comprised of 58 counties covering about 100 million acres, of which 10% are covered with hardwoods and 23% with conifers (Figure 1-1, California Lands). Intermingled ownerships of these lands occur throughout the state. Slightly more than half of the acres forested with conifers are administered by the U.S.D.A. Forest Service (Figure 2-2), with the timber industry and other private holdings owning the majority of the remaining acres. For hardwood lands, over 6.5 million acres (71%) are under private ownership. The Forest Service administers the majority of the remaining hardwood acres (Figure 2-3).

The National Hierarchical Framework of Ecological Units (Figure 2-4) is a regionalization, classification and mapping system for stratifying the Earth into progressively smaller areas of increasingly

Figure 1-3 - California Forested Acres by Ownership -- Hardwoods. (Source: FRAAP Information and Analysis System)



Percent of total (9.5 million acres)

uniform ecological potentials (Avers et al. 1993) The ecological units in California have been classified into 2 Domains, the Humid Temperate Domain and the Dry Domain. Within the Humid Temperate Domain, the ecological units have been further classified into 2 divisions, 5 provinces and 13 sections. Within the Dry Domain, the ecological units have been further classified into 2 divisions, 3 provinces and 5 sections (Figure 1-4).

This report is organized based on the province and section levels of the hierarchical framework. Disturbance agents which affect the majority of the sections within a province are discussed at the province level, while the remaining agents are discussed by section. Agents which affect vegetation throughout the state are covered individually.

A system is being developed to classify the vegetation within these ecological units, which upon completion will be incorporated into future forest health reports. However, until this system becomes available, the CALVEG classification of vegetation is used to provide the reader with some knowledge of the vegetation within the provinces and sections (Figure 2-5). This is a generalized map representing existing vegetation in California in a very broad sense. The vegetation types may have a more extensive distribution, but due to the scale of the maps the total distribution may not appear. ■

Figure 1-4 - Hierarchy of Ecological Units in California

HUMID TEMPERATE DOMAIN

Division	Province	Section
260-Mediterranean	261-CA coastal chaparral forest and shrub	261A-Central CA coast
		261B-Southern CA coast
	262-CA dry steppe	262A-Great Valley
	263-CA coastal steppe, mixed & redwood forest	263A-Northern CA coast
M260-Mediterranean regime mountains	M261-Sierran steppe, mixed & coniferous forest & alpine meadow	M261A-Klamath mountains
		M261B-Northern CA coast ranges
		M261C-Northern CA interior coast ranges
		M261D-Southern Cascades
		M261E-Sierra Nevada
		M261F-Sierra Nevada foothills
		M261G-Modoc plateau
	M262-CA coastal range open woodland, shrub, continuous forest, meadow	M262A-Central CA coast ranges
		M262B-Southern CA mountains & valleys

DRY DOMAIN

Division	Province	Section
320-Tropical/ subtropical desert	322-American semi-desert & desert	322A-Mojave desert
		322B-Sonoran Mojave desert
		322C-Sonoran Colorado desert
340-Temperate desert	341-Intermountain semi-desert & desert	341D-Mono
	342-Intermountain semi-desert	342B-Northwestern basin and range

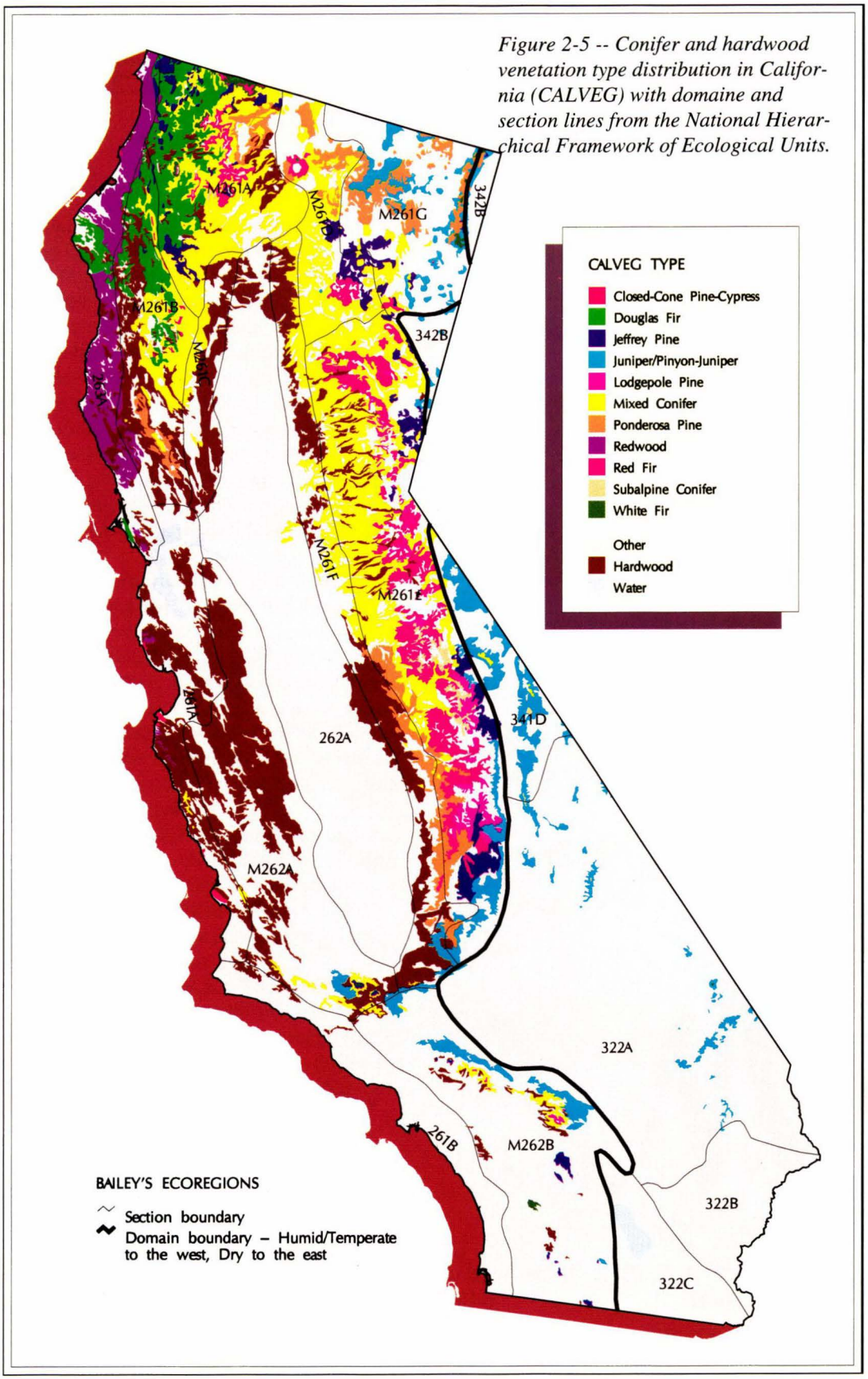


Figure 2-5 -- Conifer and hardwood venetation type distribution in California (CALVEG) with domaine and section lines from the National Hierarchical Framework of Ecological Units.

3 Influences on Forest Ecosystems

Fire

Fire is a significant component of ecosystem functioning in California forests and is recognized as an integral and important part of many terrestrial and emergent vegetative communities. Lightning has historically been a significant ignition source. The majority of lightning fires extinguish themselves at small size under natural conditions, given the absence of extreme fire weather (Keeley 1982; van Wagtendonk 1986). Native Americans purposefully set fire to wildlands, but the extent to which they engaged in these practices, and the degree to which this use of fire influenced overall fire regimes and altered fire frequencies is unknown (Husari and Hawk 1994).

According to work with tree ring chronologies in conifer stands, fluctuations in natural fire frequency and intensity corresponded to climatic variations (Swetnam et al. 1990; Swetnam 1993). Fire intervals lengthened during periods of increased precipitation. Conversely, periods of high fire frequency are usually associated with extended dry weather. With regularly occurring fires, fuels are maintained at low levels, and fires are smaller in extent, uneven in distribution, and less intense in an overall context.

Martin and Sapsis (1991) estimated that a total of 5.6 to 13.2 million acres per year burned in California prior to European presence from a combination of natural ignitions and fires ignited by Native Americans. This is over ten times the area burned annually during the past 50 years (Figure 3-1).

The attempted removal of fire from many areas in California has resulted in a great disruption of the natural fire regime, resulting in very unhealthy and unstable communities, as well as ultimately failing to remove fire. The fire return interval, seasonality, dimensions, and severity characteristics of fire regimes have often been altered to the extent that plant communities adapted to one type of fire regime have become susceptible to the altered regime. Those fires that do grow large occur under dry, windy conditions and are uniformly intense. They burn large areas while conditions are severe and are suppressed once weather conditions become moderate and firefighting resources are available. The majority of acres are burned in a few large fires. Wildfire

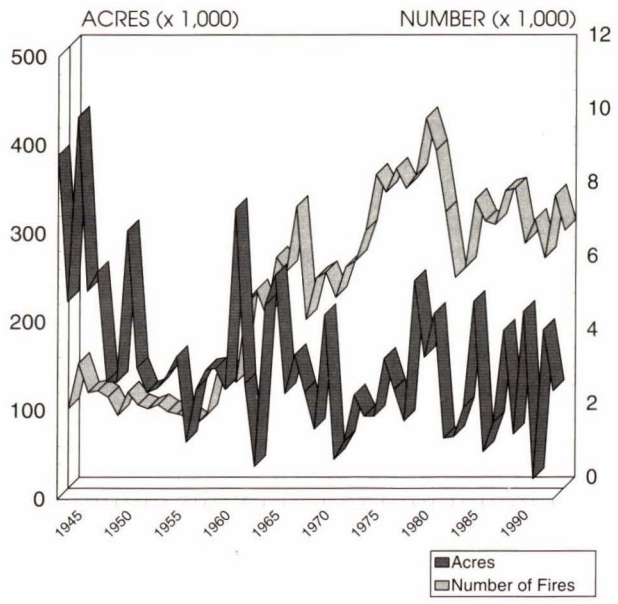


Figure 3-1 -- Wildland Fires in California on lands under California Department of Forestry and Fire Protection direct protection, 1943-1993.

acres burned, expressed as acres burned per 1000 acres protected in California, have doubled over the last 20 years with little increase in the numbers of fires (Martin and Sapsis 1991). (Figure 3-2) The rate of change toward more intense fire regimes is accelerated by management practices that increase fuel accumulation and cause shifts in species composition.

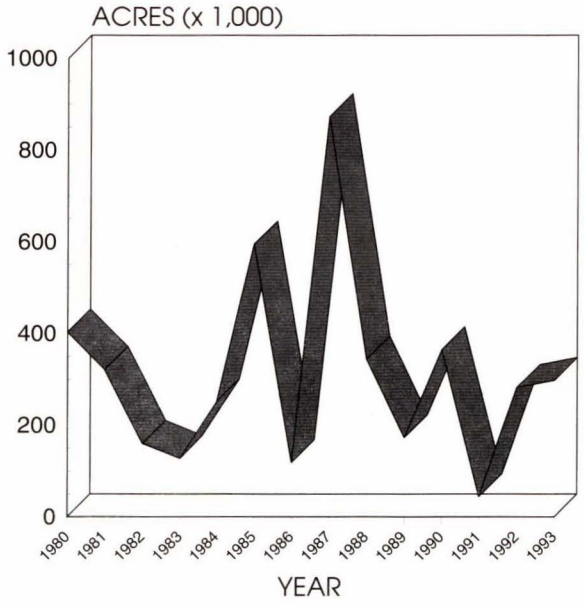


Figure 3-2 -- Total acres of wildlands burned in California, 1980-1993.

Fire interacts with other aspects of the community to affect the health of forests or other vegetative communities. This is quite apparent especially with regard to arthropods, including insects, and pathogens. Although there has been a fair amount of work done on the interaction of arthropods and pathogens, little research has involved all three agents. Many examples can be cited of past and present research where insects act as vectors for pathogens, or where they attack vegetation jointly. The injury of vegetation by fire may lead to invasion of pathogens in wound sites or to insect attack because of fire-induced stress. Fire might directly reduce the incidence of dwarf mistletoe in a stand and also, through increased vigor of the stand, allow the stand to outgrow much of the mistletoe. The removal of fire might increase total biomass on a site, often by species not adapted to these sites.

In the Sierra Nevada and Cascade Mountains, the lack of fire in some areas has allowed ponderosa pine dominated systems to grow as thickets to the stage where the smaller trees are susceptible to insect attack. In addition, older pines are also severely stressed, making them susceptible to attack. When fire is removed, it can lead to a higher incidence of insects and pathogens, and further invasion of pine or other shade intolerant species by shade tolerant fir. The fir becomes susceptible to bark beetle and defoliator attack. These examples also illustrate systems once adapted to frequent, low-severity fires, which are now susceptible to today's infrequent, high-severity fires.

Direct observations link the change in fire regimes and the loss of forest health. The indirect pathways linking fire with arthropods and pathogens in forest health are less clear, and little research has been conducted to examine the relationships. There may be far more interactions, especially of an indirect nature, than are suspected.

A major problem facing resource managers is mitigation of the effects of this long-term fire exclusion within these fire-adapted ecosystems. These effects include excessive fuels accretion, changes in forest structure and species composition, and the spectre of the unusually intense, extensive and damaging fires.

Weather

Climate patterns in California are very diverse, dependent upon topography, proximity to oceans, mountains and air drainages, and many other factors. Most of California's forests exist in a Mediterranean climate characterized by dry summers and wet winters. Mean annual precipitation varies from less than two inches in Death Valley to more than 100 inches annually in parts of Del Norte County (Figure 3-3). Temperature extremes are common, ranging from as high as 130 degrees F in the desert to subzero in the high Sierra Nevada.

Most weather-related damage to trees, other than that caused by drought, is not usually widespread in nature. Damage is isolated to small areas and is a result of an extreme or unusual weather event that generally is short-lived. Windthrow and windsnap are

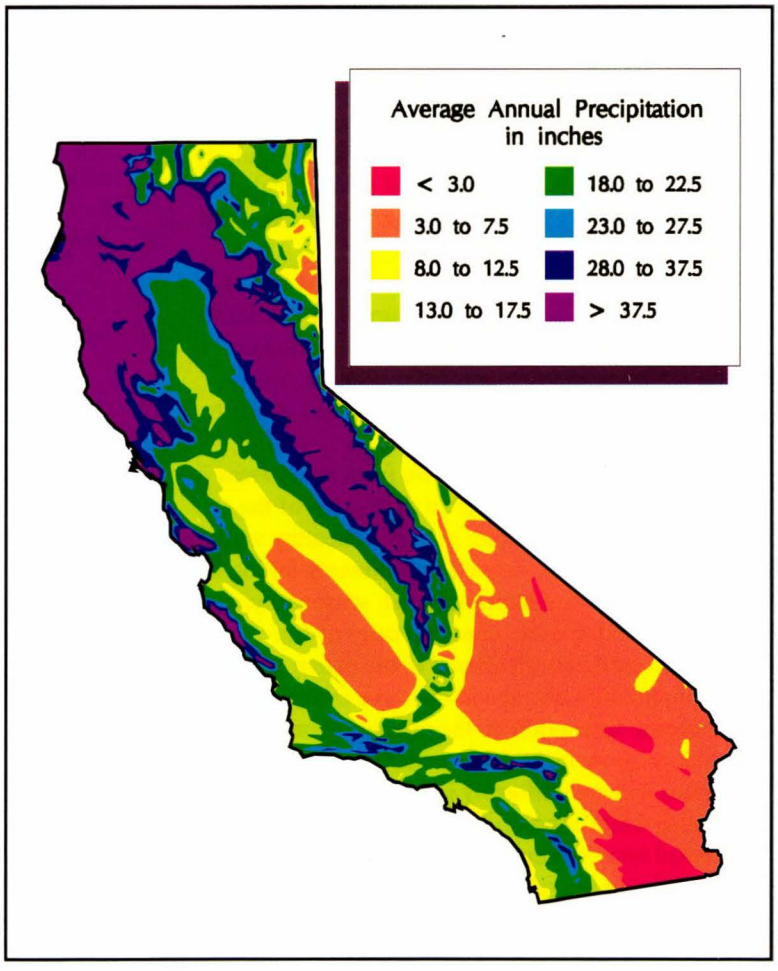


Figure 3-3 -- Long-term annual precipitation in inches for California.

High winds during winter storms can severly damage trees and other vegetation, especially on ridges. Red fir stand on the Klamath National Forest.

examples of this type of damage and may be associated with pathogens. One of the largest single episodes of windthrow in the state occurred during the Columbus Day storm, October 12, 1962. The areas most heavily damaged were the North Coast and the Yolly Bolly-Middle Eel Wilderness on the Shasta-Trinity National Forest. The primary tree species affected was Douglas-fir. A Douglas-fir beetle outbreak developed in the North Coast as a result of the blowdown. Other notable incidents of blowdown occurred during 1988 and the winter of 1992-1993 in northern California and during the winters of 1983-1985 on the Sierra National Forest.

Other kinds of weather-related events that cause damage to trees in California are frosts, hail, heavy snow, and floods. Snow breakage, resulting from a single heavy storm or continuous storms, is common during wet winters. Many conifers throughout the state were damaged as a result of heavy snow loads during the winter of 1992-1993. The most wide-spread incident of damage to forest trees in California due to flooding occurred during December 1964 and January 1965. In the northern coastal areas the water levels of many major rivers were about 30 feet above normal, resulting in extensive damage to Douglas-fir and ponderosa pine trees.

Historically, the most significant, widespread, weather-related effect on the vegetation in California has been conifer mortality associated with severe moisture stress. Conifer mortality tends to increase whenever winter precipitation is less than about 80% of the longterm normal. Trees stressed by inadequate moisture levels have their natural defense systems weakened to the point that they are highly susceptible to attack by bark, engraver and wood-boring beetles. Other factors such as root diseases, dwarf mistletoes and competing vegetation can also contribute to stress and predispose trees to attack by bark beetles. Refer to the section on Multiple-Agent Interactions for more specific information on combined effects that alter forest vegetation.

Various analyses of tree ring data suggest that the more recent drought periods (within the last 100 years) are not anomalies when considered in the long term context of the past 1,000 years (Fritts & Gordon, 1980; Graumlich, 1991; Fritts et al. 1979). The reconstruction of annual precipitation from tree ring data by Fritts and Gordon (1980) indicates that

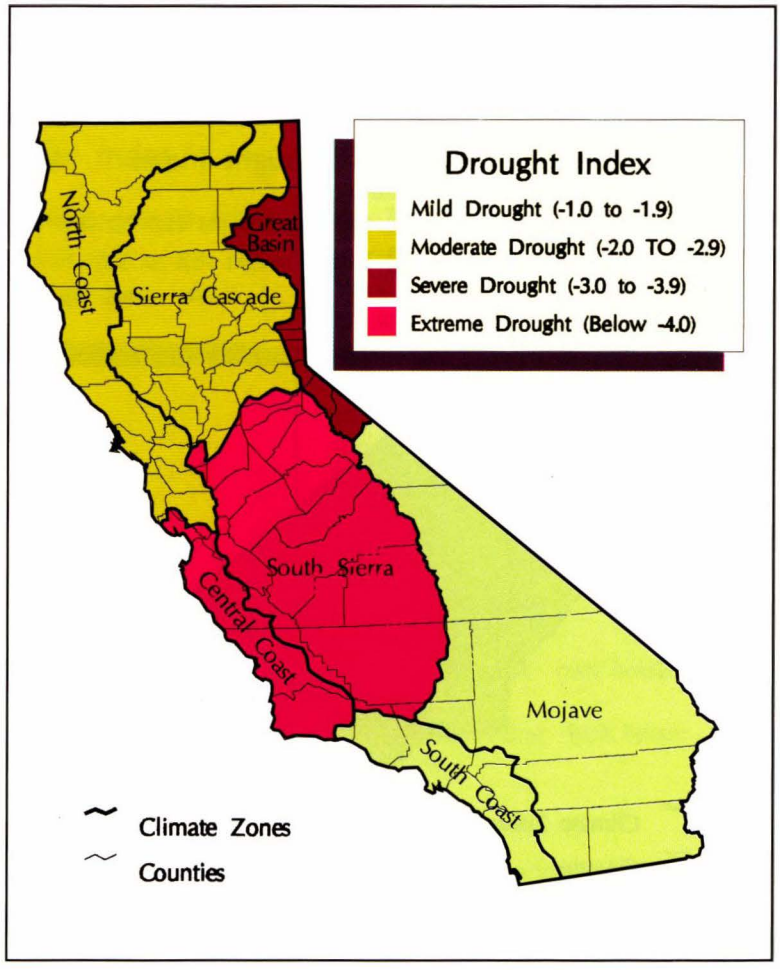


Figure 3-4 -- Palmer Hydrologic Drought Index, average for 1976 and 1977 by climate zone.

California has experienced at least 6 periods of precipitation deficit since 1600. In the perspective of a 360-year reconstruction of precipitation, the period since 1890 has been one of a precipitation surplus.

For the purposes of this report, a commonly used drought index, the Palmer Drought Index (PDI) will be used to show meteorological moisture conditions in California. The United States Department of Commerce, National Oceanic and Atmospheric Administration and the United States Department of Agriculture use the PDI to indicate prolonged abnormal conditions affecting water-sensitive economics. The Index has been calculated back to the late 1890's and provides a computationally consistent representation of meteorological moisture conditions throughout the United States.

The PDI is an index of meteorological drought or moisture excess and ranges from about -6 to +6, with negative values denoting dry spells and positive values denoting wet spells. The equations for the index are derived from monthly average meteorological data and based on the concept of a balance between water supply and demand (Palmer 1965). PDI's are calculated weekly for the seven climate zones in California.

Wide fluctuations in annual precipitation are a common occurrence in California, as are periods of extended drought. Recent moderate to extreme (on the PDI scale) drought periods in California occurred between 1959-1961, 1976-1977 and between 1987-1992. The drought in the mid-70's was most severe in the Central Coast and South Sierra climate zones (Figure 3-4) and resulted in dramatic increases in levels of tree mortality, particularly in the coniferous ecosystems in the Sierra Nevada and throughout Northern California. The most recent drought period began in 1986-1987. The PDI's for the past 7 years indicate levels of mild to extreme drought throughout much of the state. The indices for 1987-1989 and 1991-1992 are shown in Figures 3-5 & 3-6, respectively. Some relief was seen during December 1992 and the early part of 1993 when a series of storms brought the snow pack in the mountainous areas of the state above normal for the first time since 1984. Based upon the monthly PDI averages for March and April 1993, most climate zones in the state experienced normal to moist (-0.4 to 1.9) conditions. However, despite these moist spells, the annual average indices indicated that most areas in the state continued to experience drought conditions due to the inability of the water supply (precipitation and stored soil moisture) to balance out the cumulative water demand deficiencies over the extended drought period (Figure 3-7). Specific information on the effects on the vegetation related to this most recent drought can be found in the individual section-level discussions.

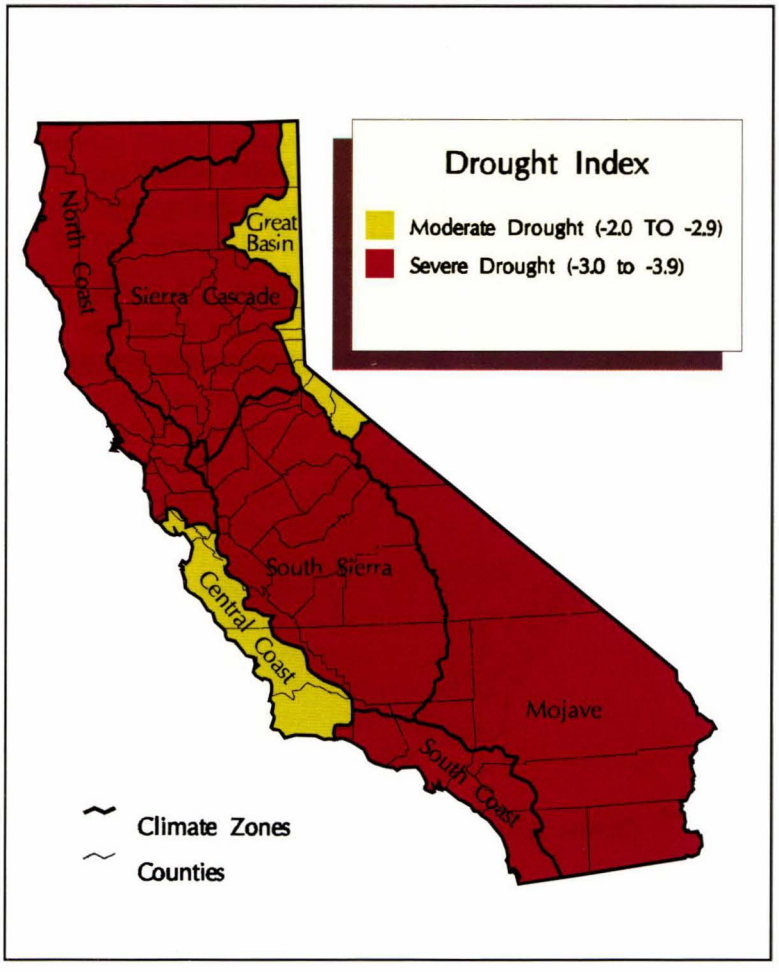


Figure 3-5 -- Palmer Hydrologic Drought Index, average for 1987- 1989 by climate zone.

Animal Damage

Tree seeds, foliage, bark, and cambium form part of the normal diet of many animals. Although most of these animals do not cause serious damage, a few species cause severe problems. Annual reports by the California Forest Pest Council (1962 through 1994) show that pocket

gophers, deer, black bears, and porcupines cause more than 80% of the animal damage on National Forest lands. Other animals that also occasionally cause damage include rabbits, squirrels, woodrats, meadow mice, mountain beavers, stream beavers, elk, domestic livestock, and some birds.

Pocket gophers, the most destructive vertebrate in the state, damage seedlings and saplings by clipping and girdling roots and stems, usually resulting in the death of the tree. Increased tree mortality from pocket gophers often can be traced to vigrous growth of competing vegetation that provides suitable habitat (Crouch 1982, Teipner et al. 1983). Problems occur in all major forest types throughout the State, but especially in eastside pine, mixed conifer, and true fir stands.

Deer feed on the foliage of seedlings, which causes suppression, growth losses and occasionally kills recently planted seedlings. Injuries from deer feeding occur throughout the State in all major forest types. Porcupines girdle seedlings, saplings, and poles causing growth loss, deformity, and dead tops. Porcupines primarily cause damage in eastside pine and true fir stands of northeastern California. Black bears peel the bark from pole sized to mature trees resulting in growth loss and death of girdled trees. Black bears are primarily a problem in Douglas-fir and redwood stands on private timber lands on the north coast of California.

The number of acres affected by vertebrates varies considerably from year to year (about 130,000 acres reported in 1993) (Figure 3-8); losses vary from 1 to 500 trees per acre. Protection from animal damage is needed on more than 50,000 acres of National Forest land each year (1989-94 survey data submitted by National Forests for the report on forest pest conditions in California), but currently only about half of these acres are treated.

Multiple-Agent Interactions

Interactions between forest vegetation and insects and pathogens are typically influenced by environmental factors. Many pathogens rely upon environmental conditions that must occur at specific times for successful infection to occur. Others may be affected by existing stand conditions such as species composition and stand density. Many forest insects are influenced by factors that affect tree health and vigor. One organism may affect a host in such a manner so as to predispose it to other organisms. Similarly, adverse site or stand conditions can weaken trees sufficiently to increase their susceptibility to attack by insects or pathogens. These situations are so common and combinations so predictable that they have been referred to as "pest complexes". In California, surveys have shown that 75 to 90% of the tree mortality in commercial forests is the result of multiple organisms or an interaction of site and stand conditions and insects. Three common interactions are:

-- dwarf mistletoe - bark beetle complexes

-- root disease - bark beetle complexes

-- overstocking - bark beetle complexes

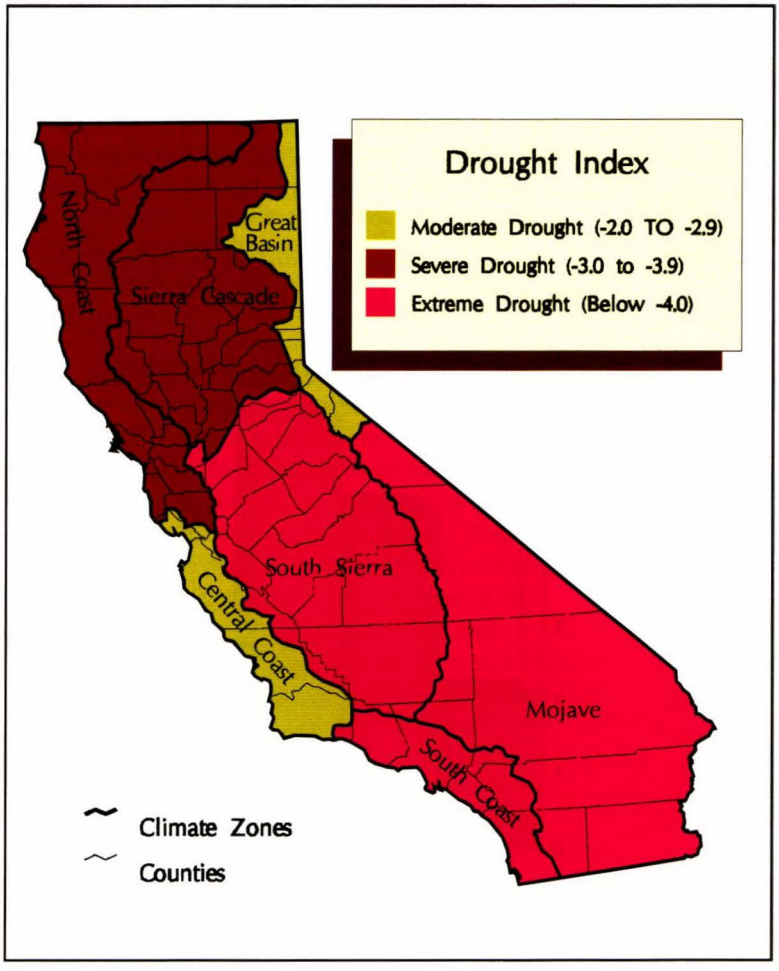


Figure 3-6 -- Palmer Hydrologic Drought Index, average for 1990- 1992 by climate zone.

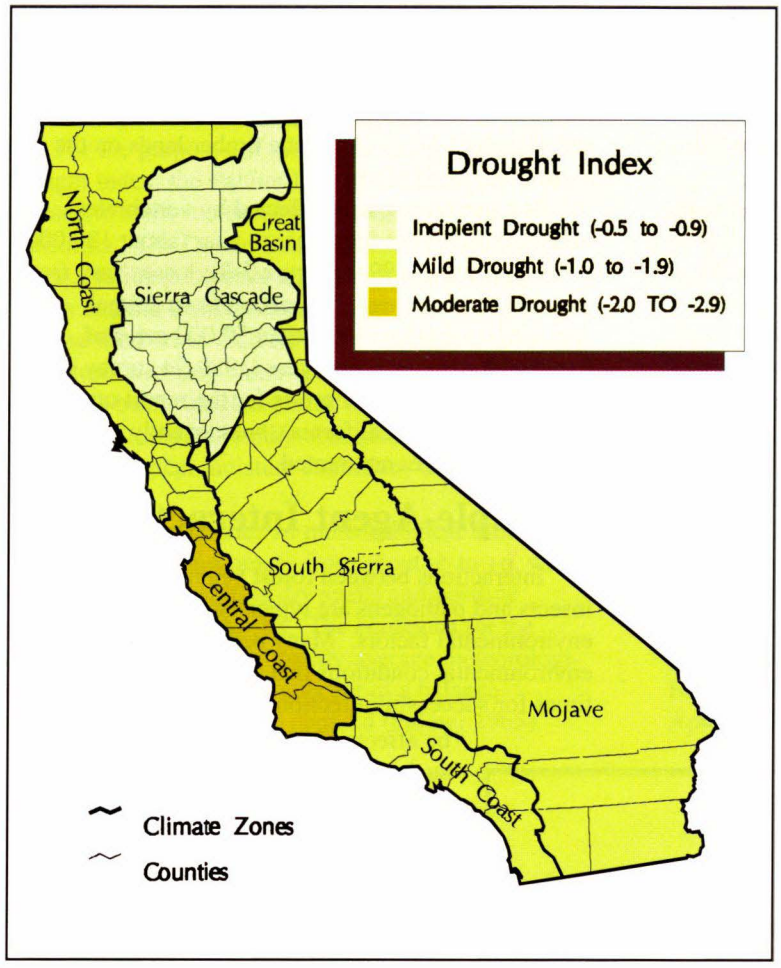


Figure 3-7 -- Palmer Hydrologic Drought Index, average for 1993 by climate zone.

In all of these interactions, the pathogen or stand condition reduces the tree's vigor and natural defenses, predisposing the trees to successful bark beetle attack.

The most important factor that influences forest health in California, as measured by tree mortality, is drought. Droughts occur periodically and with them levels of tree mortality increase. Between 1975 and 1977 northern California experienced one of its most severe droughts on record (See Weather section). Special surveys were performed to estimate the amount of conifer mortality associated with that drought and to determine the other factors associated with the mortality. Mortality rose dramatically within one year of the onset of the drought and dropped just as dramatically when precipitation returned to more normal levels (Figure 3-9). Over two-thirds of the total number of dead trees during this period were either

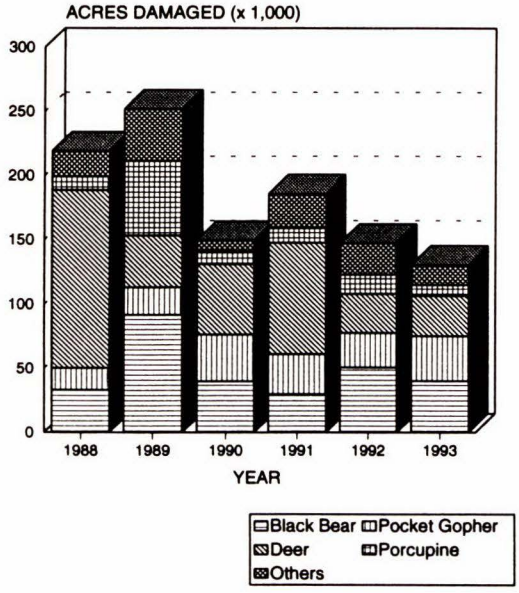
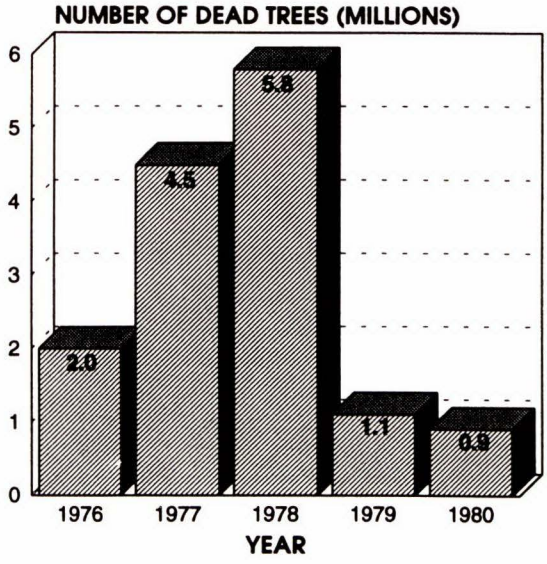


Figure 3-8 -- Number of acres in California forests reported to be actively receiving some level of animal damage and the agents causing the damage.

Figure 3-9 -- Conifer mortality in northern California related to the 1975-1977 drought.



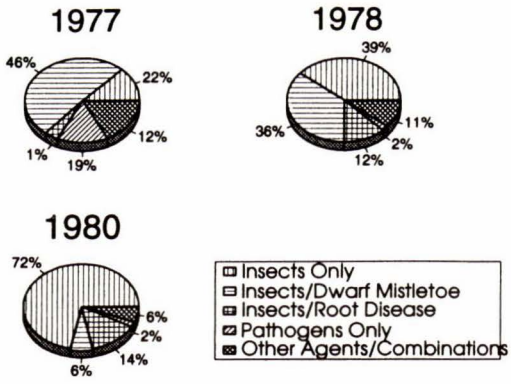


Figure 3-10 -- Agents involved in tree mortality during and following the 1975-77 drought years in northern California.

ponderosa pine or white fir. The organisms involved in the mortality changed just as dramatically as the drought progressed (Figure 3-10). In the initial years of the drought (1975-76), approximately 69% of the dead trees had some combination of insects and pathogens. In the middle year (1977-78), this proportion dropped to about 53%.

Immediately following the return to normal precipitation (1979-80), the proportion of mortality with multiple biotic agents dropped to 22%. As this proportion of multiple agents declined, insects alone, specifically bark beetles, became the dominant organisms involved in the mortality. The reasoning behind this shift was the early removal of trees already of poor vigor because of the presence of pathogens. In effect a short-term drought tends to cleanse the forest of trees with existing debilitations. After many of these weakened trees were killed, drought andincreased insect populationscontinued to kill trees that had been relatively healthy.

In addition to the interactions between organisms and the effects of drought, one other group of factors is influential in determining forest health. These factors are the site and stand characteristics where the trees grow. Sites have specific capabilities of the amount of biomass they can grow. When that capacity is exceeded mortality of the vegetation will eventually occur. There is not an absolute level for any site, but general ranges do exist for a particular quality of site. When this is exceeded the site is considered to be overstocked and mortality can be expected within the foreseeable future, especially during periods of drought.

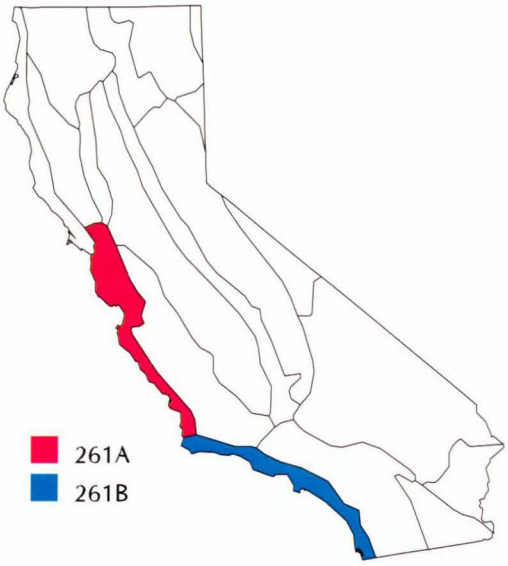
The lack of fire in many of our natural ecosystems has resulted in an increase in stocking on many sites, resulting in higher levels of tree mortality, even when minor droughts occur. The lack of fire has also altered the species composition of trees with an increase in shade tolerant species that are more prone to moisture stress. ■

4 Ecological Sections

COMBINED CALIFORNIA CHAPARRAL FOREST AND SHRUB PROVINCE

261A Central California Coast

261B Southern California Coast



Ecology

These two sections comprise California's coastline from the San Francisco Bay area southward to the Mexican border. The province is highly urbanized in the San Francisco Bay area, Los Angeles, and San Diego. Elsewhere there are less urbanized stretches of coastline vegetated with isolated native Monterey and Torrey pine stands, redwood, coast live oak, grasslands, or chaparral.

Temperature ranges become more extreme and average precipitation less in a southerly progression through the province. The central coast harbors the southern extension of coast redwood and the three native Monterey pine stands in the United States. The only native Torrey pine stands are in the southern coast section in San Diego County and on Santa Rosa Island. Elsewhere, areas of live oaks, coastal sage, perennial grasslands, or chaparral prevail, their occurrence somewhat dependent upon temperature, available soil moisture, and susceptibility to fire. Post-fire soil erosion and seismic activity can also influence the composition of native plant species.

Forest Health Issues

Monterey pine

Natural Monterey pine stands are confined to 3 coastal locations in the fog belt of Central California and on Santa Cruz and Santa Rosa Islands. Many Monterey pine Christmas tree farms are also located in the southern coastal part of the state.

Pine pitch canker is the primary agent affecting Monterey pine in California. Pine pitch canker was first detected in California in 1986 and is widespread among ornamental Monterey pine in the southeastern San Francisco Bay area, and around Monterey Bay (Figure 4-1). The disease is scattered elsewhere, mostly in coastal southern California where it also threatens several Monterey pine Christmas tree farms. Pitch canker has now extended into two of the three native Monterey pine stands. To date, the fungus has been isolated from twelve species of pine and from Douglas-fir. Various twig, cone, and bark beetles, and a weevil are strongly implicated as vectors of the disease.

Data from ninety-seven Monterey pine in Santa Cruz County monitored by the California Department of Forestry and Fire Protection from 1987-1992 illustrate the potential impact of pitch canker on this tree species. By 1992 roughly half of the trees had undergone significant decline due to the combined effects of disease and ensuing bark beetle attack, including seventeen trees which died. Conversely, about 20% of the trees showed little evidence of impact from the disease, including eight trees that showed no infections, whatsoever. Although none of the infected trees showed clear signs of recovery, there were many trees in which the infection level remained static throughout the period of observations. Due to poor regeneration, excessive tree mortality could greatly effect this native stand.

Torrey pine

The major aggregation of native Torrey pine is a 100+ acre stand within the Torrey Pine State Reserve

Figure 4-1 -- Counties with detections of pine pitch canker, 1986-1993.

in San Diego County. From winter 1988 through May 1991, the California fivespined ips killed roughly 12% of the trees. The infestation was initiated by a severe windstorm blowing down trees in which the beetles bred, and due to physiological stress of surrounding trees from drought.

Torrey pine is also susceptible to pine pitch canker. Pitch canker-infected Torrey pine could be a further attraction to the California fivespined ips. To date, pitch canker has not been detected in the Torrey Pine State Reserve. However, infected ornamental Torrey pine have been detected elsewhere in the state.

Oaks

Oaks are the dominant and most conspicuous trees throughout much of these two sections. Tree-size oaks that can be found in one or both sections include valley, black, coast live, interior live, Engelmann, canyon live, blue and island oak. Of these, coast live oak is the most widely distributed. The primary agents affecting oaks in these sections are the California oak moth, oak twig girdler and pathogens which cause twig blight and branch dieback.

The California oak moth has periodic outbreaks on the central California coast that last 2 to 3 years and recur roughly every 4 to 6 years. Coast live oak is the principal host, although other oaks are susceptible to damage. Young, overwintering larvae survive only on live oaks, which results in damage to these trees during the spring. Deciduous oaks are largely untouched by this spring generation, but a second and sometimes third generation may damage both live and deciduous oaks. While outbreaks can result in complete defoliation of trees, tree mortality is seldom a direct outcome. Forest health issues may arise in urban and recreational areas where defoliation is often viewed as aesthetically negative or when defoliation adds to other stresses, causing tree decline and sometimes mortality. In the San Francisco Bay Area, the most recent episode of widespread defoliation occurred in 1986 (Ken Meyer, pers. comm.). The oak moth is also a serious defoliator in southern California. There, it is perhaps the most important insect affecting oaks that are not suffering from drought stress (Brown & Eads 1965).

The oak twig girdler is considered to be the most important insect injuring drought stressed or similarly weakened oaks in southern California. Coast and interior live oaks are the primary hosts, although this wood borer has also been reported from Engelmann oak. Twigs up to one-half inch in diameter are killed by larval mining activity. Damage is an indicator of tree stress and is primarily considered to be a problem in ornamental settings. However, single-year incidence of twig dieback and loss of leaf area can potentially benefit trees during times of drought by reducing transpiration (Brown & Eads 1965).

Oak twig blight and oak branch dieback apparently have a wide distribution in California, but most reports have come from the central coast from Mendocino County south to Santa Barbara County.

Cryptocline cinerescens and *Discula quercina* have been implicated in twig blight, while branch dieback is caused by *Diplodia quercina*. As the common names suggest, twig blight results in the death of small diameter, current year branch tissue, whereas branch dieback kills larger branches up to many inches in diameter. Coast live oak is the primary host for twig blight fungi, but the disease has also been recorded on California white oak, black oak, interior live oak, and Oregon white oak. Branch dieback has been observed on coast live oak, California white oak, and black oak.

Weather appears to have a role in the epidemiology of both diseases. Branch dieback was first recognized as a significant problem at the end of the 1976-1977 drought and occurrence is likely associated with water stressed trees. In contrast, infection of host tissues by twig blight fungi is favored by wet weather. Twig blight is also often associated with branch infestations of the oak pit scale (Costello et al. 1989).

Considerable variability of disease susceptibility and severity has been noted in individual trees. In some cases, severe infections have caused noticeable tree decline and mortality. Research trials of pruning out infected wood, in conjunction with a preventive fungicide, indicate some success in lowering infection levels. However, such practices may only be feasible for individual or small aggregates of high value trees. Reducing infestations of the oak pit scale may also minimize twig blight occurrence.

Chaparral

For several consecutive years beginning in the late 1980's, dieback of chaparral along the southern California coast has increased fire hazard concerns. At least eight species of shrubs have experienced dieback or mortality from botryosphaeria canker. Plants may be predisposed to the fungus due to drought, air pollution, and/or other environmental stresses. Reforestation efforts in these areas, either with conifers or oak seedlings, are often impacted by the feeding of pocket gophers, ground squirrels, and deer.

Current Forest Health Activities

Research by University of California, Berkeley, continues to study the complexity of pine pitch canker - insect vector interaction. Severely infected and killed roadside pines are being replaced by non-host tree and shrub species in the Santa Cruz area. Resource managers for the native Monterey Peninsula stand of Monterey pine are considering a long-range promotion of genetic resistance for future stand tolerance of the insect/pathogen complex.

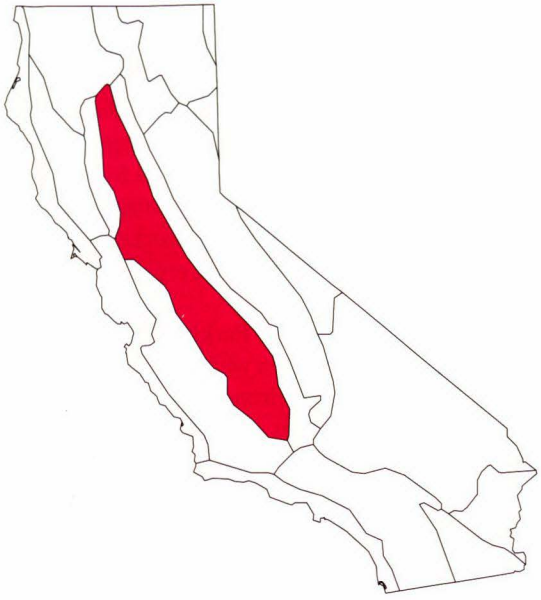
Torrey Pine State Reserve cooperated with Pacific Southwest Forest and Range Experiment Station research to implement a mass trapping program using aggregation pheromones to trap beetles in mortality areas and anti-aggregation pheromones to repel beetles in surrounding healthy areas. Even though drought conditions persisted during the two years beetles were trapped, beetle-caused mortality drastically subsided (Shea & Neustein 1993). Planting of ornamental Torrey pine near the Reserve is discouraged to avoid providing a bridge for the introduction of the pine pitch canker fungus into the Reserve. Researchers are currently working with the Reserve on ways to promote stand regenerating conditions.

The state Department of Parks and Recreation is removing exotic tree species which are highly susceptible to pest and environmental stresses, and replanting with native trees and shrubs in several State Parks.

Recent research at the University of California, Berkeley, has examined management strategies for controlling levels of oak twig decline and branch dieback.

262 CALIFORNIA DRY STEPPE PROVINCE

262A Great Valley



Ecology

California's Central Valley is a low plain stretching over 400 miles from north to south. It is rimmed by foothills and mountains with large rivers flowing into it from the Cascade mountains in the north and the Sierra Nevada to the east. The climate is characterized by cool wet winters and long, hot, dry summers. Precipitation ranges from 5 to 30 inches per year, most of it occurring from December-March. Today, the landscape is dominated by agriculture and urban areas. Forests and woodlands comprise a fraction of their original extent. In undisturbed settings, rivers and perennial streams may be bordered by lush riparian forests of cottonwood, alder, sycamore, valley oak, and other species. Elsewhere, natural landscapes may consist of valley oak woodlands and savannahs, grasslands, and marshes. Most native bunch grasses have been replaced by introduced annual grasses.

Forest Health Issues

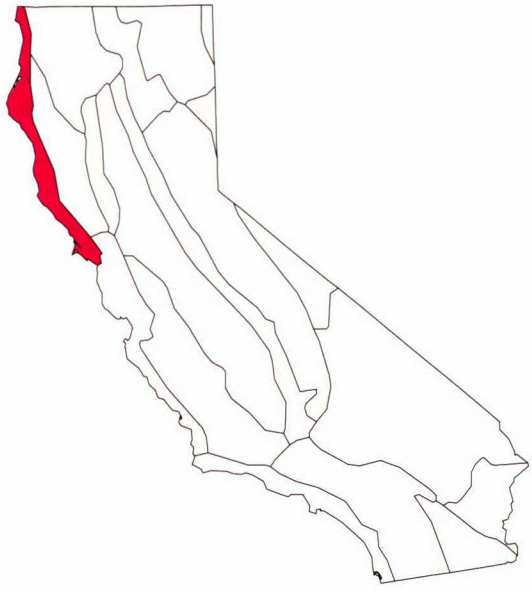
Valley Oak

Of all the native California oaks, valley oak has arguably suffered the greatest decline in numbers. Although it is widely distributed, its occurrence on accessible and prime arable land has brought it into direct conflict with agricultural and population-related development over much of its range. While significant losses have already occurred, threats from development continue. Riparian woodlands in the Sacramento Valley, of which valley oak is a primary component, are currently estimated to occupy only 1-2% of the land occupied in 1850 (Rossi 1980).

Direct loss of the resource is only one concern. Inadequate recruitment has been identified as a threat to the sustainability of remaining valley oak woodlands. Based on the occurrence of seedlings within sampling plots, a statewide assessment of California's hardwood resource indicated valley oak has the poorest regeneration of any of the state's tree-size oaks (Bolsinger 1988).

263 CALIFORNIA COASTAL STEPPE, MIXED FOREST AND REDWOOD FOREST PROVINCE

263A Northern California Coast



Ecology

The California Coastal Steppe, mixed forest, and redwood Province has only one section, the Northern California Coast section. Topography is dominated by coastal parallel ridges to 3000 feet in elevation and lower rounded crests elsewhere from the San Francisco Bay north to the Oregon border. The average temperatures (50-to-55 F) are modified by coastal fog

and sea breezes. Annual precipitation averages 40-to-100 inches. The section has a history of moderate- to high-intensity stand-replacing fires. The coastline has also been home to several large, destructive earthquakes: the estimated 6.5-to-7.0 magnitude 1898 earthquake between Albion and Mendocino, Mendocino County, the 8.3 magnitude 1906 San Francisco earthquake (epicenter at Olema, Marin County) and the 6.2 magnitude 1991 Honeydew earthquake (epicenter near Petrolia, Humboldt County).

Old growth and second growth redwood forests dominate the northern two-thirds of the section. Many groves of old growth redwoods are incorporated into the national and state park system and are protected from commercial harvest. Other conifer species include Douglas-fir, Port-Orford cedar, Sitka spruce, grand fir, western hemlock, Bishop pine, and Monterey cypress. Pacific madrone and tanoak can also be found mixed with the coniferous species. Less forested areas have coastal live oak, coastal sage, and many plants in the coastal shrub series.

Forest Health Issues

Redwood

The primary agent affecting redwoods is black bear. Damage is caused by the bears peeling the bark with their teeth and then eating the cambial layer. Pole-sized to about 25-inch diameter trees are preferred targets. Bark is stripped off the stem to a height which can no longer support the bear's weight. Damaged trees may be partially or completely girdled. Trees with partial girdling may develop wood decay originating at the site of exposed wood. Damage usually occurs from May through early June in the northernmost counties. In many cases, bear damage follows within two years of thinning operations. Other conifers, mainly pole-sized Douglas-fir, are also hosts for similar bear damage.

Supplemental bear feeding has been researched, but no practical and effective management practices are available or known to prevent or drastically minimize bear damage following thinning operations.

Douglas-fir

Black stain root disease is the most prevalent pathogen of Douglas-fir throughout this section and elsewhere in Douglas-fir stands in northern California (Figure 4-3). Trees of all sizes can be killed by this wilt fungus. Once introduced into the root system, the fungus inhabits the vascular tracheids, minimizing water transport to the crown. The fungus may spread

Black bear damage on second-growth Douglas-fir. Large strips of bark at the base of the tree, exposed wood, and vertical teeth marks on the bole are characteristic of black bear feeding on the cambium and inner bark (photo courtesy Weyerhaeuser Corp.).

from tree to tree via adjacent or adjoining root systems, or can be vectored into roots of either healthy trees, injured stems, or recently created stumps by root-breeding beetles and weevils (Hansen et al. 1988). In California no other hosts are known for this strain of black stain. There appears to be a relationship between occurrence of this disease and soil disturbance. Thinning activities may also influence the presence of this disease (Harrington et al. 1983).

Young trees can be killed within a couple of years of disease symptom expression, whereas large diameter trees may survive for longer periods of time. Mortality of pole-sized trees may be accelerated by the Douglas-fir engraver beetle, Douglas-fir pole beetle, or silver fir beetle, and large trees by the flatheaded fir borer and/or Douglas-fir beetle. Decline and mortality of large trees is usually limited to groups of two to three trees. Large numbers of dead trees are usually only seen in seedlings and saplings. Not all infected trees have obvious crown decline symptoms, so it is often difficult to identify all infected trees within an infected area.

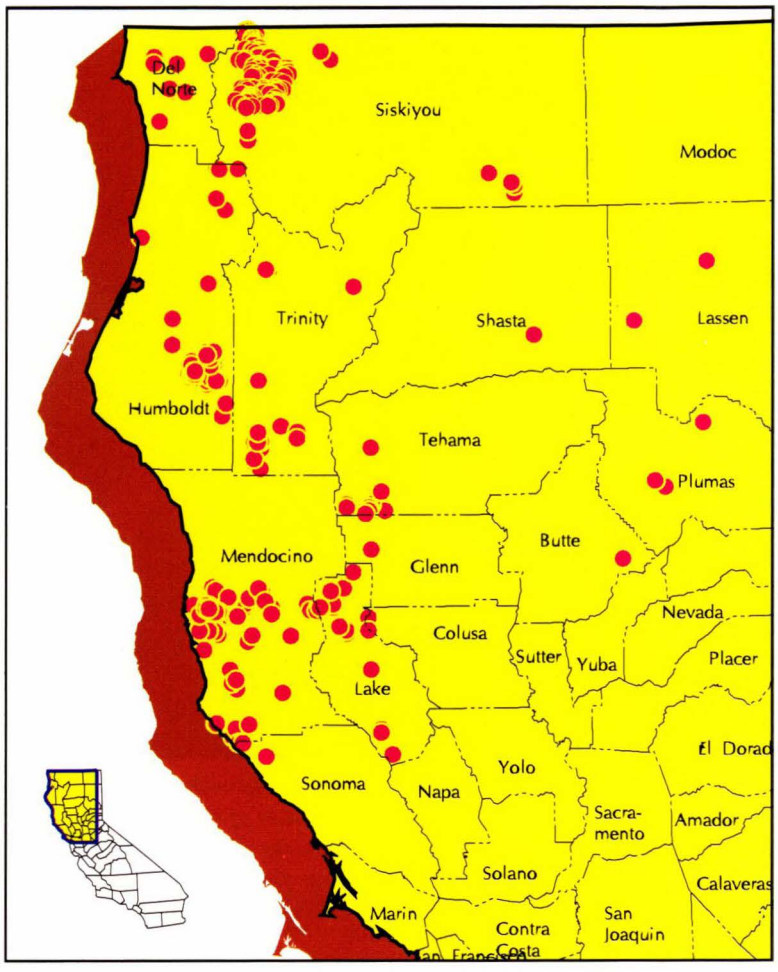


Figure 4-3 -- Known locations of black stain root disease infecting Douglas-fir in northern California.

There are no practical methods for controlling black stain root disease once established within a stand. However, strategies are recommended which minimize site attractiveness to insect vectors of the pathogen. These strategies include minimizing site disturbance (road or skid trail construction and harvest activities), manipulating species composition, and restricting thinning activities.

Port-Orford-cedar

The southern extension of native Port-Orford-cedar stands in the Pacific northwest is primarily in California's two northwestern coastal counties. Isolated interior stands are found in the upper Trinity and Sacramento River drainages. Port-Orford-cedar root disease was first detected in native Port-Orford-cedar in Oregon in 1952. The disease was detected in northern California in 1980 (Kliejunas & Adams 1980). In 1989 the fungus was first isolated from Pacific yew. The approximate distribution of Port-Orford-cedar and the root disease in California on federal lands are illustrated in Figure 4-4.

This water-borne fungus has motile spores which move downslope and downstream in water. Infection occurs when spores come in close proximity to feeder roots. Other spore types of this pathogen are transported overland principally by human activities, although some animals may also transport them. These spores are moved in organic matter in soil mainly on vehicles and logging and road maintenance equipment. Once infection occurs, the fungus grows through the host to the root collar where it girdles the tree. Cedar bark beetles and wood borers often attack the stems of dying trees.

Recent surveys indicate that about 5% (9,000 acres) of the land with Port-

Port-Orford-cedar with Port-Orford-cedar root disease and cedar bark beetles.

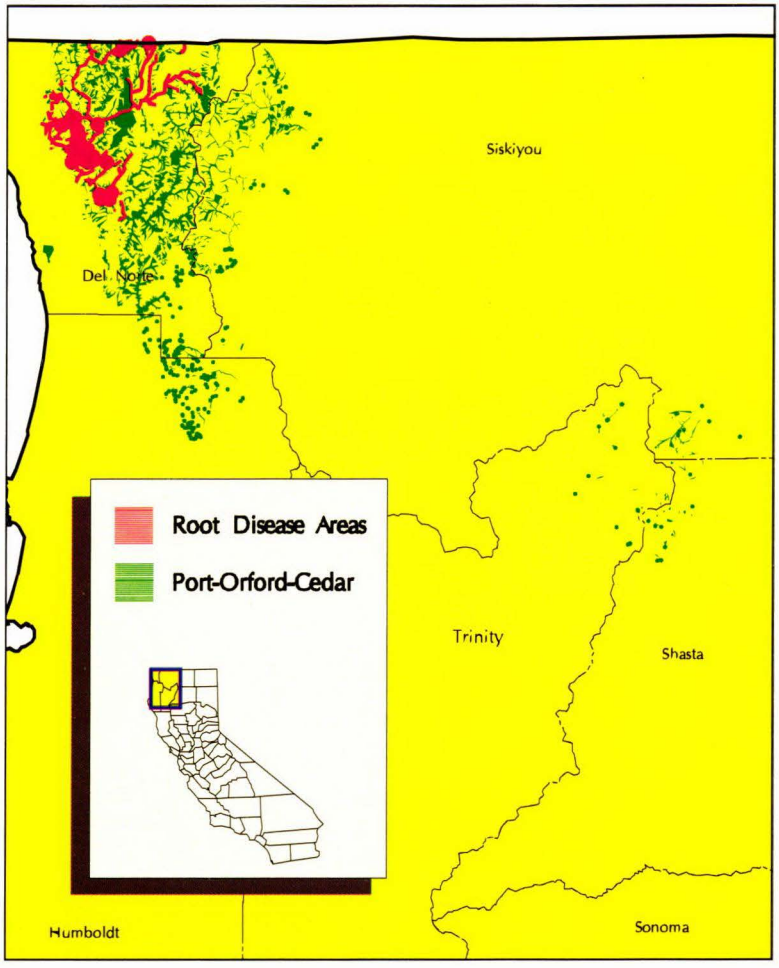


Figure 4-4 -- Approximate distribution of Port-Orford-cedar on National Forest system lands in California and areas infested by Port-Orford-cedar root disease.

Orford-cedar on the National Forest in this section is infected by this pathogen. An interregional and interagency coordinating group provides guidance on Port-Orford-cedar management for the federal agencies. Strict mitigation measures and subsequent monitoring are required when activities that pose a risk to Port-Orford-cedar are planned. Such measures include restricting the season of activity, washing equipment, closing roads, timing entry into areas, and removing potential hosts along roads.

Pacific madrone

Varying levels of a lethal canker disease are found throughout much of the range of Pacific madrone in California. Madrone canker infects young branches and progresses into larger branches, and can eventually kill stems. Killed branches have the appearance of being fire scorched. The madrone canker fungus also commonly causes dieback in manzanita, ceanothus and ornamental giant sequoia. Disease severity notably increased over the past decade on madrone and other hosts.

Current Forest Health Activities

Epidemiology of black stain root disease in Douglas-fir is under study. Manipulation of site attractiveness to insect vectors may minimize disease spread.

Bear damage to second growth redwood and Douglas-fir follows thinning operations. Supplemental feedings seem impractical and bear hunting to reduce populations is opposed by many.

The spread of Port-Orford-cedar root disease is of major concern and mitigation measures are placed on timber harvest and other operations to prevent or minimize spread. USDA Forest Service has a road closure program to prevent vehicular transportation of the fungus into susceptible host areas.

M261 SIERRAN STEPPE, MIXED FOREST, CONIFEROUS FOREST, ALPINE MEADOW PROVINCE

Ecology

This province includes most of the coniferous lands in California. This is a large and diverse province. Most of the area is steeply sloping to precipitous mountains crossed by many valleys having steep gradients. Elevations range from 2,000 to over 14,000 feet. Precipitation is highly variable, depending on latitude, elevation, and aspect.

The east slope of the Sierra Nevada range receives considerably less precipitation than the west side. The vegetation is highly diverse, reflecting the influences of geology and climate. At lower elevations on the west side, grey pine and oaks dominate the landscape above grasses and evergreen shrubs. These forested landscapes are interspersed with grasslands and chapparal. With increasing elevation the conifer component increases, first becoming dominated by ponderosa pine, then a mixture of ponderosa pine, Douglas-fir, sugar pine, incense-cedar and white fir commonly known as the "mixed conifer" type. The hardwood component also changes from blue oak and valley oak to California black oak. The mixed conifer-hardwood community grades increasingly to white fir at higher elevations, with an increasing component of red fir. At higher elevations a subalpine zone is present which is composed of red fir, mountain hemlock, lodgepole pine, and western white pine. Coniferous species with limited ranges, including whitebark, limber, bristlecone, and foxtail pine, can be found in different locations just below timberline.

Forest Health Issues

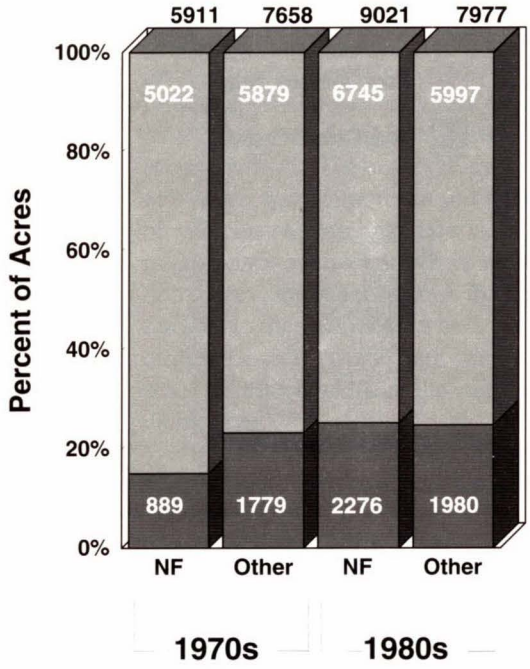
The condition of the forests in this province varies somewhat by section. Several issues are influential in the condition of the forests in most, if not all, of the sections in the province. These issues are widespread and cross section boundaries, and will be discussed as a group for the province. The issues include human intervention, dwarf mistletoes, white pine blister rust, and bark and engraver beetles.

Multiple Hosts (All species)

Human intervention has been a significant factor affecting the health and condition of these forests. Past harvesting practices, mining, development, and fire suppression have altered the species composition and size class distributions in many areas. These activities have also influenced the effects and occurrence of insects and diseases in this province.

Multiple Hosts (Pinaceae Family)

Dwarf mistletoes are parasitic seed plants that attack members of the Pinaceae family. Twelve dwarf mistletoe species have been identified in this province. They are relatively host specific and require a living host for survival. These agents cause a reduction in the rate of growth of a tree, the development of



Ownership	Years	Total Acres	Area Infested	% Area Infested
National Forest	1970s	5,911	889	15%
Other Ownerships		7,658	1,779	23%
Total		13,569	2,668	20%
National Forests	1980s	9,021	2,276	25%
Other Ownerships		7,977	1,980	25%
Total		16,998	4,256	25%

Figure 4-5 -- Forested area (1,000 acres) in California infested with dwarf mistletoe, Arceuthobium *spp., in the 1970s and 1980s. (Information for the National Forests in the 1970s includes only nine northern California National Forests. Information for the national forests in the 1980s does not include the five southern California National Forests.)*

deformities such as witches' brooms and cankers, and increase the tree's susceptibility to attack by bark beetles. Dwarf mistletoes commonly interact with other factors, including stocking, precipitation, and insects, to affect their host. The shoots and seeds of dwarf mistletoes provide food to various species of insects and wildlife. Fire is an important player in the ecology of these parasites. Dwarf mistletoes play a role in the type and severity of fire in some situations.

Dwarf mistletoes have been inventoried on forest lands for over twenty years in California (Figure 4-5). Inventories in the early 1970's identified dwarf mistletoes on about 25% of non-National Forest System lands (Bolsinger 1978). This is the same level of infection identified on these lands in the early 1980's (Bolsinger, personal communication). On nine National Forests, the area infested in the early 1970's was 15% (Bolsinger 1978). A comparable estimate for 14 national forests in northern California in the 1980's was 25%. These areas include some acreage from the Northern and Central California Coast sections and Central California Coast Range section, and only include commercial forest lands.

Figure 4-6 -- Percent of cubic volume by host species infected by dwarf mistletoes, Arceuthobium *spp., in the 1980s on commercial timberland in California. (Excludes the five southern California National Forests.)*

Host Species	National Forests	Other Ownerships	Total
White Fir	5.2	15.8	**7.6**
Red Fir	11.7	14.0	**11.9**
Knobcone Pine	0.9	7.7	**8.1**
Lodgepole Pine	9.1	7.7	**8.9**
Jeffrey Pine	5.1	9.3	**6.2**
Ponderosa Pine	6.5	8.0	**7.0**
Sugar Pine	5.3	3.1	**4.7**
Bishop Pine	—[1]	6.5	**6.5**
Grey Pine	0	10.0	**8.1**
Western White Pine	2.6	—[1]	**2.6**
Coulter Pine	0	—[1]	**0**
Douglas Fir	1.9	3.0	**2.4**
Western Hemlock	—[1]	3.1	**3.1**
Mountain Hemlock	0.05	—[1]	**0.05**
Brewer Spruce	0	—[1]	**0**
Total	**5.6**	**7.3**	**6.1**

[1] This species was not identified in the inventories on this land ownership

The incidence of individual species of dwarf mistletoes is relatively low on all land ownerships (Figure 4-6). It does appear that there is a relationship between the incidence of dwarf mistletoe and the amount of the host that exists. It is not too surprising that the true firs, red and white fir, have some of the highest incidences since they appear to tolerate infection better than the pine species.

Bark and engraver beetles play a significant role in the health of California's forests. Damage caused by this group of insects is primarily expressed as mortality and top-killing. This occurs in all years and is associated with overstocking, disease, or other stress agents. During periods of drought, bark beetle related mortality increases significantly. California underwent a serious drought from 1975 to 1977. Tree mortality surveys were initiated during and following this period and provided information on the additional mortality experienced during this drought (Figure 3-7). A second drought occurred from 1987 through 1992. Although not as intense, it lasted considerably longer and eventually mortality levels increased substantially.

Sugar pine

Sugar pine is an important component of the mixed-conifer ecosystem of California. Its range extends from the northern mountains of the Coast Range to Lake and Sonoma Counties and down the Sierra Nevada range to Baja California. White pine blister rust is an introduced fungus that was first identified in northern California in 1929 near Happy Camp (Siskiyou County). It has since spread throughout most of the range of sugar pine in northern California (Figure 4-8). It has also been identified on western white pine, whitebark pine, limber pine, and foxtail pine in certain locations in northern California.

The principal effect of blister rust is mortality of trees that become infected. Smaller trees die more rapidly. Surveys in limited areas identified 20% or more of the trees as having infections that will result in tree mortality (DeNitto 1987; Kliejunas 1982, 1984). Most mature trees survive infection, although in some locations the number of infections in a tree is great enough that the tree has a higher susceptibility to bark beetle attack. This disease is likely affecting the size class distribution of sugar pine and limiting regeneration in areas with high susceptibility to infection. Blister rust also infects most species of *Ribes*, but the only injury is occasional premature defoliation. The association between the pines and *Ribes* is important in the life cycle of the fungus.

Figure 4-8 -- Approximate spread of white pine blister rust in California and the range of its major conifer hosts.

Ribes germinate readily when soils are disturbed and increased sunlight becomes available. Higher levels of infection in plantations are probably a result of increased numbers of *Ribes* and more favorable microclimates.

Current Forest Health Activities

Damage associated with dwarf mistletoes is usually reduced during silvicultural activities by removing infected trees and regenerating sites with non-hosts. In addition to on-going silvicultural projects, specific projects occur with dwarf mistletoe suppression being the primary objective. The National Forest System treated or surveyed over 15,500 acres in this province for dwarf mistletoe management using Forest Pest Management suppression funds during 1993.

An active white pine blister rust resistance breeding program is in place in California. Candidate sugar pine trees are screened for resistance. Seed is then collected and sown from trees identified as having resistance. This program has identified 540 resistant sugar pines on all ownerships in the state. Currently, an additional 1,350 families are being screened. In addition to the major gene resistance, multiple gene resistance mechanisms are being explored and candidates screened.

Prevention is the key to minimizing bark beetle-related impacts. Prevention is normally focused on reducing stress on the trees, competition for soil moisture and effects of diseases. Thinning stands to lessen inter-tree competition is a major prevention activity. In some situations where trees have individual high values, such as in campgrounds and at residences, specialized prevention activities may be appropriate. This may involve treating trees with insecticide to reduce the risk of successful insect attack. These activities are discussed under each section.

M261A Klamath Mountains

Ecology

The Klamath Mountains section is located in northwestern California. It has the wettest climate in California with warm, dry summers and cool, wet winters. It has a west to east and northwest to southeast moisture gradient with the northern and western sides receiving considerably more moisture than the southern and eastern sides. Analysis of precipitation records indicates that there have been alternating periods of relatively wet and dry conditions that last for a few decades each. The higher levels of precipitation have resulted in periodic floods in the Klamath River watershed. The most notable floods were in 1861-62, 1889-90, and 1964-65.

The elevation in this section ranges from sea level to 8,000 feet. The major rivers run westerly in deeply incised canyons. Moderate to steep slopes arise from these canyons. Geologically, it is one of the more complex sections in North America. Both the Siskiyou and Klamath Mountains are found in this section.

The existing vegetation of the Klamath Mountains section can be divided into five major categories, including conifer forest, hardwood/conifer forest, hardwood forest, montane chapparal, and grasslands. Conifer forests may include Douglas-fir, white fir, red fir, Port-Orford-cedar, mountain hemlock, knobcone pine, lodgepole pine, Jeffrey pine, incense-cedar, redwood, western white pine, ponderosa pine, and grey pine. Hardwoods include tanoak, California black oak, Oregon white oak, Pacific madrone, and coast and canyon live oaks. A large number of sensitive and endemic plant species are found within this section.

Forest Health Issues

Douglas-fir

Douglas-fir occurs mainly on steep, middle and upper one-third slopes at lower elevations in this section. It experiences many of the same issues as are observed in the Northern California Coast section (263A), including black stain root disease and drought-related mortality. Flatheaded fir borer is the primary insect affecting Douglas-fir. A single outbreak of the Trinity budworm has been recorded.

Black stain root disease is a serious pathogen, especially in younger stands. Plantation surveys have found it to be common, causing considerable damage in some situations. Surveys of Douglas-fir plantations on the Gasquet Ranger District, Six Rivers National Forest, in the mid-1980s found that 11 out of 30 had black stain root disease present (DeNitto 1985). Out of 22,000 acres of Douglas-fir plantations surveyed in 1993 on the Happy Camp Ranger District, Klamath National Forest, over 3,000 acres had black stain root disease present in the plantation. Similar surveys of 15,500 acres of Douglas-fir plantations on the Orleans Ranger District, Six Rivers National Forest, identified black stain root disease in plantations with a total area of 2,775 acres.

The recent drought has had a strong influence on Douglas-fir health. Smaller trees under severe moisture stress have been attacked by several canker fungi and lesser bark beetles. Larger drought-stressed trees have been attacked and killed by the flatheaded fir borer, particularly in trees on marginal sites in the Klamath and Trinity River canyons. The interaction of drought, poor site quality, overstocking, and soil moisture competition has resulted in significant levels of Douglas-fir mortality. Aerial surveys on the Klamath National Forest in 1993 identified about 7,500 acres of Douglas-fir with levels of mortality above normal for that area. Aerial survey maps of this mortality are included in Appendix A.

The Trinity budworm defoliated Douglas-firs and, to a lesser extent, white fir around Clair Engle Lake in the early 1980s (Dale 1983, 1984a, 1984b, 1985). This was only the second report of defoliation by this insect. The amount of defoliation increased from 32,000 acres in 1982 to 130,000 acres in 1984. The defoliation decreased dramatically in 1985 following the aerial application of *Bacillus thuringiensis* and the occurrence of a cold, wet spring

during the period of larval development. No recurrences of this insect have been observed.

White Fir

White fir occurs on middle to upper slope positions at mid-elevation in this section. It may be the dominant overstory species or mixed with Douglas-fir, ponderosa pine, incense-cedar, red fir, and sugar pine.

As in the rest of California, white fir has been undergoing above normal levels of mortality in the Klamath Mountains section during the recent drought. Although not as extensive as in the Sierra Nevada and Modoc Plateau sections, high levels of white fir mortality have been observed, especially on drier, overstocked sites. Severe moisture stress is the underlying cause of this mortality, but fir engraver beetle and flatheaded fir borer are usually found in the dying trees. An area with particularly noticeable mortality is around the west and north sides of the Scott Valley on parts of the Klamath National Forest. Aerial surveys of mortality on the Klamath National Forest in 1993 indicated that about 55,000 acres of white fir had levels of mortality above the historic average level.

Ponderosa Pine

Ponderosa pine is not as extensive in this section as elsewhere in the state. It is usually a component of a mixed conifer-hardwood type at lower elevations on drier sites.

The principal forest health issue for ponderosa pine in the Klamath Mountains section is mortality associated with drought. Common insect associates include western pine beetle, red turpentine beetle, pine engraver beetles, and California flatheaded borer (see Multiple-Agent Interactions). Several concentrations of mortality were noted in 1993 in the Klamath River Canyon and Shasta Valley (Siskiyou County), and Hayfork Valley (Trinity County). Aerial surveys for the Klamath National Forest in 1993 estimated around 82,000 acres with higher than normal levels of pine mortality.

Fallen white fire with annosus root rot.

Sugar Pine

Sugar pine is found in a wide array of situations in this section. It usually occurs as a single tree or small clumps on mesic sites with deep soils. It can also be found on drier sites with rocky, ultramafic soils.

White pine blister rust is the primary agent affecting sugar pine in this section (see M261 Province discussion). Sugar pine mortality, caused by drought and mountain pine beetle, was scattered across the section in 1993. Specific areas of higher mortality were in Indian Valley-Hyampom, Scott River, South Fork of Salmon River, Klamath River, and Elk Creek drainages (Siskiyou and Trinity Counties).

An outbreak of sugar pine needle cast was present in 1993 along the South Fork of the Scott River. In a few cases, the defoliation was sufficient to add additional stress to the trees which resulted in successful mountain pine beetle attacks. Trees which were not attacked by mountain pine beetle recovered from the needle cast and only had thinning of their crowns.

Hardwoods

Numerous species of hardwoods occur in this section, including tanoak, black oak, white oak, canyon live oak, bigleaf maple, and Pacific madrone. They are scattered in various forest types and sites depending on their environmental requirements.

In 1993, foliage diseases were common on hardwoods. A late spring rain appeared to be conducive to infection by numerous fungi. Examples of those identified include *Mycosphaerella fraxinicola* on Oregon ash, *Cylindrosporium alni* on red alder, and unidentified species of *Cylindrosporium* and *Septoria* on oaks. These pathogens did not result in tree mortality, however their symptoms were quite apparent to the public.

Current Forest Health Activities

The Klamath Mountains section has several inland populations of Port-Orford-cedar that are currently not infested with Port-Orford-cedar root disease. Port-Orford-cedar and its root disease are discussed in section 263A, Northern California Coast section. Activities, such as seasonally closing roads

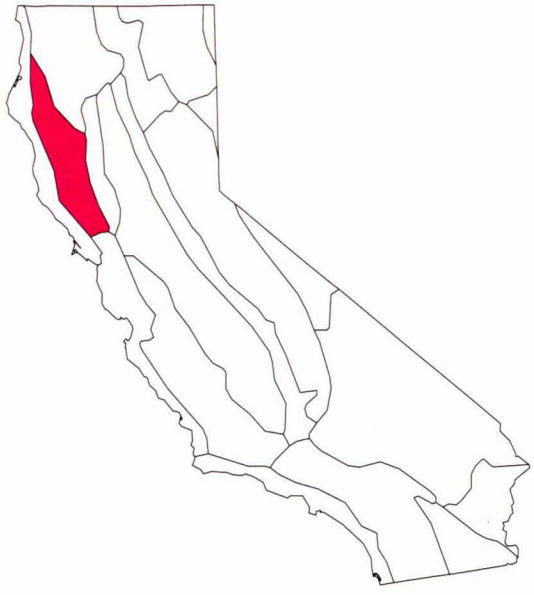
and limiting access to areas with Port-Orford-cedar, are taking place in some areas to limit the possibility of introduction of this fungus. When ground-disturbing activities do take place in areas with Port-Orford-cedar, vehicle and equipment cleaning are required prior to entry if they have been in areas where the root disease is present.

Above normal levels of western pine beetle-related mortality were detected in a recreation area on the Mendocino National Forest early in 1993. Live ponderosa pines within a 20-acre area were sprayed with carbaryl to protect them from attack.

Young sugar pines in plantations are at risk of infection by white pine blister rust. Over 33 acres of plantation on the Mendocino National Forest received treatment to reduce that risk. Sugar pines in these plantations were pruned of their lower limbs to remove existing infections and to reduce target area for future infection.

Because of the continuing drought, an aerial survey to determine the amount of mortality was completed on the Klamath National Forest in 1993 (Appendix A). This Forest has a total forested land base of approximately 1.5 million acres. Mortality was found to be higher than normal on about 155,000 acres. This includes all species of conifers. As discussed above, this high level of mortality is principally a result of drought and insect interactions.

M261B Northern California Coast Ranges



Ecology

The Northern California Coast Range section topography varies from level terraces to moderate- to steep-sloped hills aligned in parallel ranges, extending from 1,000-to-7,000 feet in elevation. Landslides have played a dominant role in shaping the land surface. Many of the soils are shallow and gravelly, have low water holding capacity, and are low in productivity. Annual precipitation ranges from 30-to-80 inches, with the higher elevations receiving much of their precipitation in the form of snow. Large, stand-replacing fires have shaped the species composition of the forests, with fire frequency increasing in the drier, brushier southern portion of the section.

Vegetation composition also changes along with the section's moisture gradients: moisture decreases from north-to-south and west-to-east. It increases from low to high elevations. Dominant conifer species are ponderosa pine, Douglas-fir, sugar pine, and white fir. Hardwoods either intermingled with the conifers or in hardwood forests are black oak, white oak, canyon live oak, tanoak and Pacific madrone.

Forest Health Issues

Ponderosa pine and sugar pine

Increased mortality of both ponderosa and sugar pines have been observed primarily due to severe moisture stress and bark beetle activity (See M261 Province discussion). Western pine beetle is the most common mortality agent associated with ponderosa pine. However, it is common to have western pine beetle, red turpentine beetle, and California flatheaded borer attacking the same tree. In addition, pine engravers are frequently associated with top and branch kill and can kill entire trees in the smaller diameter classes. Sugar pine tends to be killed by the mountain pine beetle and the California flatheaded borer. White pine blister rust also affects sugar pine in this section (See M261 Province discussion). In the southern portion of this ecological section, both pine species can be predisposed to bark beetle attack by annosus root disease.

Douglas-fir

The pimary agent affecting Douglas-fir in this section is black stain root disease. As in the Northern California Coast section (263A), infected trees are often killed in association with the flatheaded fir borer. However, many other Douglas-fir trees are killed solely by the flatheaded fir borer. Presumably,

trees under moisture stress are successfully attacked, regardless of root disease incidence. Where Douglas-fir grows in conjunction with many black oaks, armillaria root disease (likely *Armillaria ostoyae*) has been recovered from trees recently killed by the flatheaded fir borer.

White fir

This tree species is somewhat scattered or in small groupings at the higher elevations. During drought periods mortality increases from attacks by the fir engraver beetle. Observations do not point to an association of annosus root disease as a common predisposing factor to fir engraver attack as reported in the Sierra Nevada.

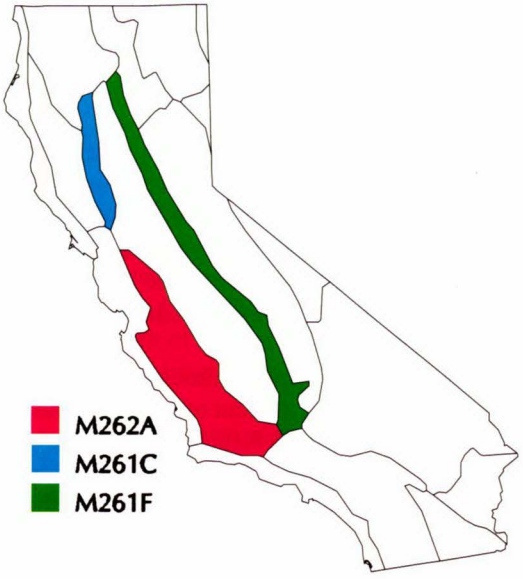
Current Forest Health Activities

Mitigation measures are placed on commercial timber harvest operations to reduce the build-up of pine engraver beetles in pine slash. Populations produced in slash can emerge and attack surrounding trees. In ponderosa pine, if pine engraver beetles cause top-kill, the trees may be more susceptible to attack by western pine beetle.

To reduce pine stump colonization by the annosus root disease fungus, stump surfaces of pines in areas of the disease occurrence have been treated in the past with granular borax. Currently, state registration has been discontinued for granular borax, but a water-soluble borate salt is available.

Sugar pines resistant to white pine blister rust on the Mendocino National Forest have been treated to protect them from attack by bark beetles during the current extended drought periods. Several different treatments have been employed, including removing surrounding competing vegetation, deep watering, and spraying with carbaryl insecticide. The treatments appear to be effective in that none of the treated trees have died.

M261C Northern California Interior Coast Ranges
M261F Sierra Nevada Foothills
M262A Central California Coast Range



Ecology

These three sections form a ring around California's Central Valley. Elevations range from 200 to 3,500 feet and precipitation ranges from 10 to 40 inches per year, generally decreasing with decreasing elevation and latitude. Winters are cool and wet, with average minimum temperatures above freezing and little, if any, snow. Summers are long, hot, and dry. Blue oak, grey pine, and interior live oak are perhaps the most representative trees, although many other species are regionally and locally abundant. Numerous large rivers flow westward through the Sierra Nevada foothills and into the Central Valley. In contrast, far fewer perennial streams and rivers flow from the Coast Ranges into the Central Valley. Reservoirs, whether on perennial or intermittent stream courses, are a common feature of all three sections.

Forest Health Issues

Blue oak

Hot dry slopes around the great Central Valley and in the Coast Ranges largely define the range of blue oak. When compared to other oak species, blue oak typically dominates on the harshest sites. Thin

soils, low precipitation, and high temperatures are characteristic. The precarious nature of this habitat is reflected in the crowns of older trees which show considerable evidence of dieback and regrowth.

Much of this habitat has traditionally been used for livestock grazing. Removal of oaks to improve livestock forage was practiced for many years, but recent studies have shown that forage production and quality is often better beneath tree canopies (Holland 1980, Holland & Morton 1980), particularly on drier sites (McClaran & Bartolome 1987). Rangeland clearing has declined considerably in recent years (Bolsinger 1988). Fuelwood harvest is another activity that has impacted and continues to impact the resource. Although the overall level of harvest represents a small proportion of the hardwood rangeland acreage, locally high levels of harvest have created concern. Monitoring by the California Department of Forestry and Fire Protection from 1988 to 1992 showed that over 50% of the volume of oak firewood harvested statewide came from two counties — Shasta and Tehama. In Shasta County, harvest exceeded growth (IHRMP 1992).

A recent threat to oak woodlands in the foothills and elsewhere is urbanization. Conversion to residential and commercial development has taken the lead as the major cause of oak woodland decline (Bolsinger 1988). Although many trees often remain following conversion, the habitat is significantly altered. Additionally, individual trees are often adversely affected by site disturbance and incompatible landscaping practices. Many native oak species do poorly in the presence of summer irrigation, with blue oak appearing to be the least tolerant. Armillaria root disease and *Phytophthora* spp. have been implicated in the death of many oak species in irrigated situations (Raabe 1980).

Blue oaks killed by excessive water and armillaria root disease.

Insect defoliators have been active in recent years in the upper Sacramento Valley. An outbreak of the Pacific tent caterpillar occurred in 1987 and 1988 followed by a lesser outbreak of an oak leaf skeletonizer, from 1990-92. Defoliation can also be caused by other agents. Dry spring weather and high summer temperatures can result in leaf fall as early as July. Wet spring weather can promote foliage diseases. In 1993, following one of the wettest springs on record, anthracnose fungi caused widespread damage to leaves and premature leaf fall starting in August (Owen 1994).

Decline and mortality of mature blue oaks is associated with long-term infection by decay and canker rot fungi. *Inonotus andersonii* was the most common of these fungi in an extensive survey of insect and disease impacts on rangeland oaks (Swiecki et al. 1990).

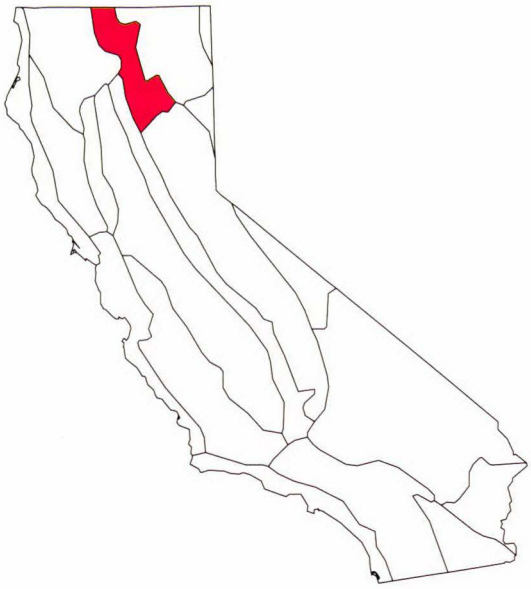
Oaks and Drought

Although native California oaks are generally considered to be drought resistant, reports indicate that recent drought conditions (1986-1987 to 1991-1992) resulted in decline and mortality of some oak trees, particularly on poorer sites. During a 4-year study of valley, blue, and coast live oaks in Santa Barbara, San Luis Obispo, and San Benito Counties, approximately 10% of the study's trees underwent severe decline or died by 1992 (Tietje et al. 1993). In a separate study conducted during the same four years, mature valley oaks growing on shallow soil in Oak Grove Regional Park near Stockton (section 262A) suffered 34% mortality on non-irrigated sites (Hickman 1993). In both studies, the prevailing drought was the primary factor linked to tree decline and death.

Current Forest Health Activities

More than ten years ago the State Board of Forestry recognized the need to better address issues and concerns related to the state's native hardwoods, particularly its oaks. In 1986, the Integrated Hardwood Range Management Program (IHRMP) was initiated in response to this need. The program is responsible for research, monitoring, and educational activities related to rangeland oaks. Major participants in the program are the University of California, the California Department of Forestry and Fire Protection, and the California Department of Fish and Game. Recently, the IHRMP has received additional direction from the State Board of Forestry to promote oak conservation at local and county levels.

M261D Southern Cascades



Ecology

The Southern Cascades section extends north from the Sierra Nevada mountains and lies between the Modoc Plateau to the east and the Klamath Mountains to the west. Its topography is comprised of volcanic mountains that are in various stages of erosion. There is no distinct mountain range in this section. Elevation ranges from 1,500 to 14,000 feet. Average annual precipitation is from 20 to 80 inches. Rivers in this section flow westerly to the Klamath and Sacramento Rivers. Vegetation in this section has been altered by mining, grazing, forestry, recreational activities and changes in fire patterns. Wide fluctuations in weather patterns have also resulted in significant changes to the biological communities found here.

The existing coniferous and hardwood vegetation is comprised of grey pine, blue oak and black oak, and canyon live oak at the lower elevations. Dogwood and big leaf maple dominate the low elevation riparian areas. A mixture of ponderosa and sugar pine, Douglas-fir, black oak and Oregon white oak and a limited amount of white fir is found as elevation increases. Mid-elevational zones are primarily occupied by white fir with a lesser component of sugar pine, ponderosa pine, and incense-cedar. Jeffery pine is generally found at higher elevations and on drier sites. Alder and cottonwood are found in the riparian areas. The high elevations are occupied by red fir, lodgepole pine and white bark pine.

Forest Health Issues

The impact of drought is the most important forest health issue for this section. The precipitation years of 1990-1992 were two of the driest during the recent drought, resulting in tree mortality due to bark beetles over most of the section. On some sites, tree mortality has been well above 50%. The long-term trend is toward species conversion on marginal sites and reduced stocking elsewhere.

Jeffrey Pine

Jeffrey pine is well represented in the southern

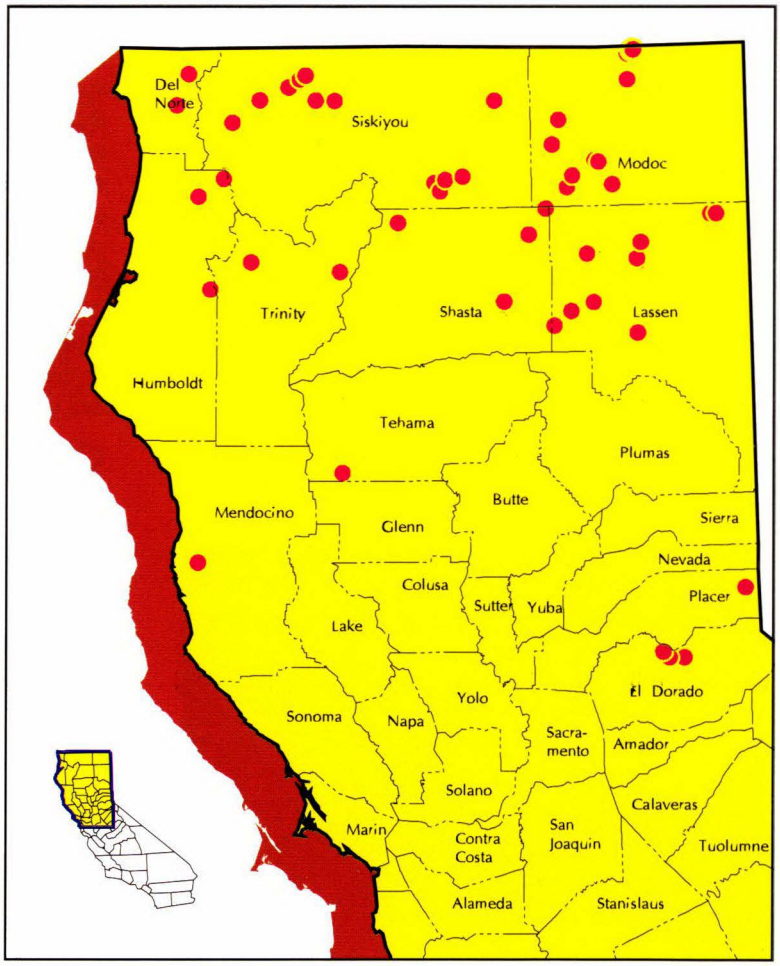


Figure 4-8 -- Known locations of black stain root disease infecting ponderosa and Jeffrey pines in northern California.

half of the section, generally tolerating cooler and drier conditions than the closely related ponderosa pine. North of the Pit River it is rare (Griffin and Critchfield 1972). Although drought tolerant, Jeffrey pine suffered from the severe drought conditions of 1991 and 1992. Tree mortality due to the Jeffrey pine beetle has been increasing, particularly in and around Lassen National Park and areas to the east. While drought has been the primary cause of increased beetle activity, black stain root disease and competition with understory white fir were some other site-specific contributing factors.

Lodgepole Pine

Lodgepole pine is found at higher elevations or in frost pockets at medium elevations. The largest areas of recent lodgepole pine mortality due to drought and subsequent attack by the mountain pine beetle are north and northeast of Mount Shasta on the Goosenest Ranger District of the Klamath National Forest. This mortality has increased steadily over the past few years. Mortality reported in 1993 — representing trees killed in 1992 — covered nearly 12,000 acres. Mortality was also reported from Lassen National Park and the Thousand Lakes Wilderness Area, Lassen National Forest.

Ponderosa Pine

Ponderosa pine is well distributed throughout the section, forming pure stands at lower elevations and being a major component of mixed conifer stands at mid elevations. It and white fir are the most abundant conifers in this section.

Several organisms have been involved in the decline of ponderosa pine in combination with the effects of drought. The western pine beetle is the insect responsible for tree death in most cases. Significant increases in western pine beetle activity were reported for 1992 and 1993. The brief respite from drought in 1993 appears to have had little influence on mortality levels. Mortality has been severe from the Burney Basin east through the Fall River Valley on the driest sites. Large contiguous areas of mortality were initially noted on Soldier and Saddle Mountains and south of the Pit River. Mortality is now pervasive throughout the area and concern is being expressed over the possible conversion of some sites to non-timber species.

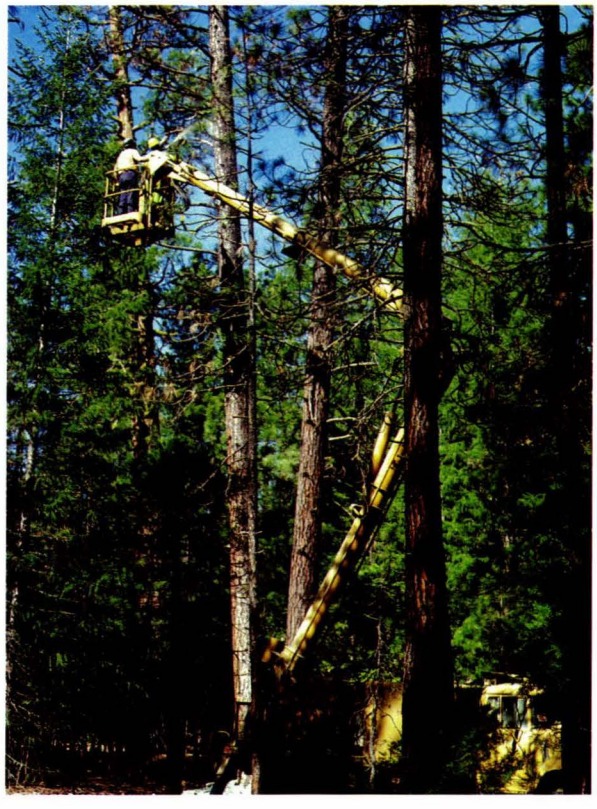
Black stain and annosus root diseases are locally important at sites scattered throughout the section. On sites in the McCloud Flats area where ponderosa pine has been harvested, levels of stump infection by *Heterobasidion annosum* average about 15-20% (DeNitto 1988). Evidence suggesting that black stain root disease may be promoted by certain harvest and pre-harvest activities is a cause for concern among land managers. The distribution of black stain root disease in ponderosa pine and Jeffrey pine is shown in Figure 4-9. At McCloud Flats, southeast of Mt. Shasta, ponderosa pine mortality is a chronic problem due to widespread occurrence of black stain root disease and western pine beetle activity. Mortality reported in 1993 was higher than normal. Black stain root disease and western pine beetle are also causing widespread tree mortality in the vicinity of Pondosa.

The black pineleaf scale has been in outbreak in eastern Shasta County — Burney Basin east through the Fall River Valley — since 1991, suggesting scale abundance may be drought related. This area, however, has a long history of repeated scale outbreaks not necessarily related to drought. This recent rise in scale abundance concurrent with extreme drought conditions has caused widespread crown thinning and tree decline. On some sites, scale abundance appears to be as important as drought in predisposing trees to western pine beetle attack.

Sugar Pine

Sugar pine is a component of mixed conifer forests over a wide range of elevations. Its distribution

Western pine beetle preventative insecticide treatment, Burney Falls State Park.



is fairly continuous in the southern half of the section, but becomes disjunct in the drier landscapes to the north. In recent years, significant losses have occurred on drier sites. Widely scattered sugar pine mortality due to the mountain pine beetle was reported in 1992, while relatively few reports were received in 1991. An early, dry spring in 1992 apparently extended the developmental period for bark beetles, as evidenced by a second generation of mountain pine beetle observed at some mid-elevation sites in the fall of that year. Mountain pine beetle-related mortality increased again in 1993.

Thin foliage at the tops of trees provided evidence of widely distributed infestations of the black pineleaf scale during 1991 and 1992. Some mountain pine beetle activity was associated with scale infestation, but it was difficult to separate the influence of drought from that of the scale. During non-drought periods, infestations of black pineleaf scale on sugar pine are rarely associated with tree mortality. Above normal precipitation in 1993 allowed many trees that were suffering from scale infestation to produce an improved complement of foliage.

White fir

As the abundance of ponderosa pine decreases with increasing elevation, white fir becomes increasingly abundant. Both species are major components of mixed conifer forests, with white fir dominating and eventually forming pure stands at higher elevations and ponderosa pine dominating and eventually forming pure stands at lower elevations.

Of all the conifer species, more white fir trees died as a result of the drought than any other. Most of this mortality was attributed to the fir engraver beetle, although the roundheaded fir borer and flatheaded fir borer were also involved. While mortality was elevated throughout the drought, it was during the past few years that the greatest increases were seen. The success of fir engraver beetle attacks is closely related to tree resistance. Ample precipitation during the winter and spring allowed many trees to pitch beetles out.

Although white fir mortality has been spectacular, most resource managers would agree that drier eastside sites were supporting more white fir than could be sustained for a long period of time. Fire suppression and selective logging have contributed to an increased abundance of fir — stocking levels were too high on many true fir sites and firs were dominating on sites that historically were dominated by pine.

Annosus root disease center in white fir.

Current Forest Health Activities

At Latour State Forest, the California Department of Forestry and Fire Protection has an ongoing program to identify and protect sugar pines resistant to white pine blister rust. Because of the drought and the threat of mountain pine beetle attack, rust-resistant and potentially rust-resistant trees have been treated annually with protective sprays of carbaryl. This effort will continue until the threat of tree mortality declines.

Because of extremely high levels of drought-related tree mortality, the State Board of Forestry has designated most of the Southern Cascades and areas to the east as a "Zone of Infestation." Such a designation serves to recognize forest pest problems of a serious nature and widespread occurrence. It also provides a mechanism for state participation in and cost-share funding of control efforts, if need be. State efforts have concentrated on educating landowners, foresters, and timber operators about drought-related pest problems and mitigating forestry practices. Similar designations exist for the Sierra Nevada and forested areas of Southern California.

M261E Sierra Nevada

Ecology

The geomorphology of the Sierra Nevada section is described as a block mountain range which is tilted west. Elevations range from 1,000 to 14,495 feet. Precipitation averages 20 to 80 inches a year which mostly occurs during fall, winter and spring. Rivers flow west in deep canyons to the Great Valley section. Rivers to the east of the crest terminate in the Mojave Desert, Mono and Northwestern Basin sections. Many of these rivers are diverted for hydroelectric power, agriculture, municipal and domestic use. Forests in this section have been altered by grazing, mining, forestry, recreational activities and changes in fire patterns. There are many small towns scattered throughout the foothills and some also located in the higher elevations.

Interior live oak, blue oak and grey pine are found at the lower elevations along the foothills. Ponderosa pine, incense-cedar, and black oak replace the foothill species as elevation increases up the slopes of the Sierra Nevada. Sugar pine, incense-cedar, white fir and ponderosa pine are found at mid-elevation with the precentage of ponderosa pine decreasing and white fir increasing as elevation increases. The dominant hardwood species in these areas are canyon live oak, maple, dogwood and black oak. White fir occupies thousands of acres in this section, primarily in areas that were logged or burned during the last century (Eyre 1980).

Red fir is found on both the east and west slopes in the Sierra Nevada from about 7,000 to 9,000 feet. The subalpine areas are comprised of lodgepole pine, western white pine and mountain hemlock. Jeffrey pine replaces ponderosa pine at high elevations and on colder sites. In this ecological section, Jeffrey pine is primarily found on the east side of the Sierra Nevada range at elevations between 5000 and 6,500 feet. Species associated with Jeffrey pine include white fir, incense-cedar and lodgepole pine. Alder is often found along stream banks and meadows adjacent to red fir, lodgepole pine and Jeffrey pine. Willow and quaking aspens are also found throughout the moist areas at high elevations.

Forest Health Issues

Giant Sequoia

Giant Sequoias are found in 75 scattered locations within a narrow 260-mile long belt in the Sierra Nevada range at elevations between 4,500 and 7,500 feet. It is not uncommon to find old-growth giant sequoia trees in their native range that are 1500 years old and over 15 feet in diameter at breast height. These trees are found primarily in Yosemite, Sequoia and Kings Canyon National Parks, and on the Sequoia National Forest. The present location of giant sequoia groves is influenced by the interaction of soil moisture, temperature and site disturbance events.

Uprooting and stem breakage of giant sequoia is a persistent problem, particularly in high recreational use areas such as National Parks. Interest in public safety and the protection of giant sequoias has led to various studies to determine the causes of uprooting and stem failure of these large trees (Piirto 1977; Piirto et al. 1984 a,b). Thirty-three tree failures were evaluated in these studies. Of the 33 failures, 7 trees apparently fell mainly because of poor footing (wet soil, stream undercutting, etc.), 22 because of the failure of decayed roots and 4 because of stem breakage.

Annosus root disease was the most common factor found in failures involving the root system. The same form of annosus root disease that infects white fir also infects giant sequoia and may be transmitted between these two hosts via root contacts. Annosus root disease spreads through the roots and root crown into the lower trunk of its host, where it causes a butt rot of the heartwood which increases its susceptibility to failure.

Jeffrey pine

Jeffrey pine is an important ecosystem component throughout the eastern portion of the Sierra Nevada ecological section. Jeffrey pine beetle, ozone,

annosus root disease and dwarf mistletoe (see M261 Province discussion), are currently the primary agents affecting the condition of Jeffrey pine in California. Historically, the pandora moth has caused defoliation of Jeffrey pine in Mono, Tulare and Kern Counties, however, it has not been detected in recent years.

Above normal levels of Jeffrey pine mortality have been observed on the east side of the Sierra Nevada range since 1990. The mortality is primarily due to interactions between drought, overstocking, and pathogens which have weakened the trees to the extent that they have been successfully attacked and killed by Jeffrey pine beetle. Pockets of infested and older dead Jeffrey pine trees were detected on the Inyo National Forest during 1993 north of the Mammoth Lakes area. However, the majority of Jeffrey pine mortality over the past few years has occurred in the Lake Tahoe Basin, particularly on the east and south sides of the lake. The mortality on the east side is of particular concern because of high public use and the presence of high value developed campgrounds and resorts (Wenz & Pronos 1993). Mortality over the past few years has occurred as large, overmature, individual pines and in small (2-5 trees) and large (20-25 trees) groups. Almost 1,400 Jeffrey pine trees have been killed since 1982 by Jeffrey pine beetle in high value areas around Lake Tahoe.

Several Jeffrey pine stands on the Inyo National Forest were surveyed for annosus root disease during 1990. The results of the survey concluded that Jeffrey pine stump infection averaged 43% (Pronos & Harris 1991). These root disease centers result in openings which usually continue to enlarge until they reach barriers such as other openings or groups of non-host plants.

The pandora moth periodically defoliates pine trees in the western part of the United States. Outbreaks in California on Jeffrey pine have occurred at about 20 to 30 year intervals and lasted from six to eight years. The most recent recorded outbreaks in California occurred between 1959-1966 and 1978-1982 (Figure 4-9). Outbreaks in California prior to 1959 were not recorded; however, the familiarity of the Native Americans in this area with this insect as a food source suggests that prior outbreaks have occurred.

Pandora moth larvae feed on the pine needles and cause varying levels of defoliation. Light to heavy Jeffrey pine defoliation occurred during the 1959-1966 outbreak on about 7,500 acres in Tulare and Kern Counties, however there are no reports of associated tree mortality. The outbreak during 1978-1982 covered an estimated 16,000 acres in Mono County with defoliation ranging from light to severe.

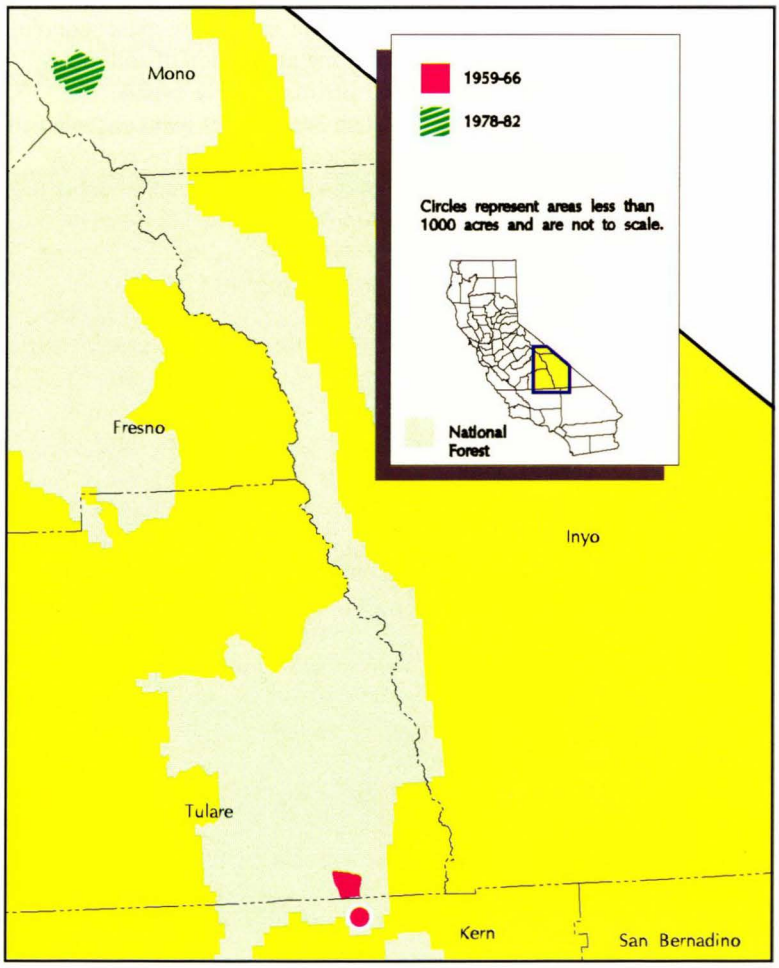


Figure 4-9 -- Areas of Jeffrey pine defoliation by pandora moth; 1959-1966 on the Sequoia National Forest; 1978-1982 on the Inyo National Forest.

Lodgepole pine

Lodgepole pine is found at higher elevations (6,500-10,000 feet) throughout the Sierra Nevada. It most commonly exists with other subalpine species, but can also be found in nearly pure stands and is common around meadows in the high Sierra. The most significant biotic agent affecting large acres of lodgepole pine in the Sierra Nevada ecological section is the lodgepole needleminer. Mountain pine

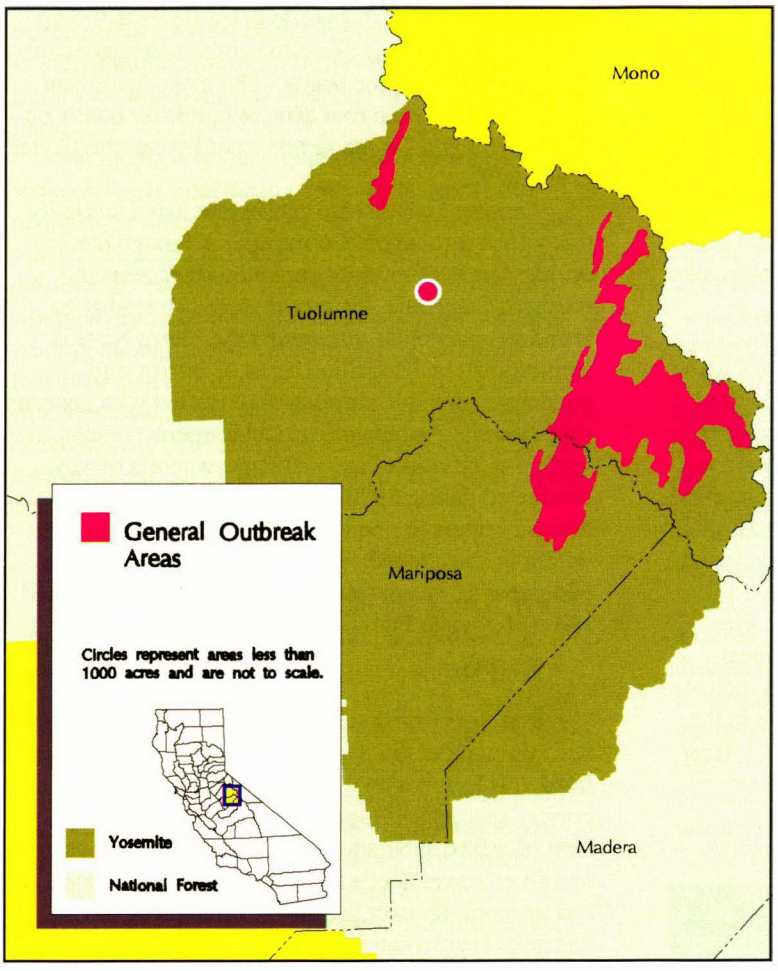


Figure 4-10 -- General areas of lodgepole pine defoliation by lodgepole needleminer in Yosemite National Park.

beetle and dwarf mistletoe also affect lodgepole pine in this section. The extended drought conditions and overstocking have lead to above-normal levels of lodgepole pine mortality, primarily due to an increase in susceptibility to successful attacks by the mountain pine beetle. Recent lodgepole pine mortality has occurred on about 1,000 acres on the Sierra National Forest. Dwarf mistletoe in lodgepole pine is primarily a concern in recreational sites, particularly campgrounds.

The lodgepole needleminer attacks and kills indigenous lodgepole pine forests in the western United States and Canada. Lodgepole needleminer populations are affected by natural enemies, disease and available food and weather (Struble 1972). The rise and fall of populations appears to primarily be associated with weather conditions (Koerber & Struble 1971). Three major infestations in California have been reported since 1900 (1903-1921, 1933-1941 and 1947-1963). Most outbreaks have occurred in Yosemite National Park (Figure 4-10), however, infestations have also occurred in Sequoia-Kings Canyon National Park. The 1947-1963 outbreak affected more than 90,000 acres in Yosemite National Park. Tree mortality can occur as a direct result of consecutive lodgepole needleminer defoliations or more commonly, weakened trees are attacked and killed by mountain pine beetle. Entire stands of lodgepole pine (over 6,000 acres) were killed in Yosemite National Park between 1953 and 1963.

The death of extensive stands of lodgepole pine results in vegetational changes within these ecosystems. Grasses, and other shade-intolerant species characteristic of dry meadows, occupy areas until they are out competed by lodgepole pine seedlings. Evidence is strong that over the course of several hundred to a thousand years, repeated needleminer outbreaks have been followed by successive replacements of lodgepole pine forests (Struble 1972).

Ponderosa pine

Ponderosa pine is found throughout the west side of the Sierra Nevada mountain range at elevations between 1,500 to 3,500 feet in the northern portion and between 5,300 to 7,300 feet in the southern portion. It is commonly found in pure stands and also as a significant component in the low elevation mixed conifer zones. Over the past several years the primary

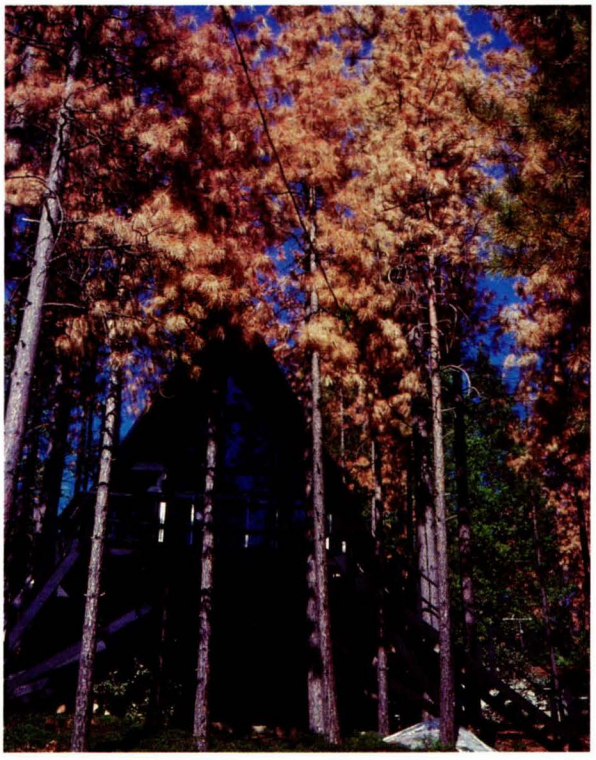
Damage caused by lodgepole needleminer, Yosemite National Park.

agent affecting the condition of ponderosa pine within the Sierra Nevada ecological section has been the western pine beetle. The primary pathogens affecting ponderosa pine in this section are black stain root disease, annosus root disease and dwarf mistletoe. Interactions among these agents, combined with moisture stress and overstocking, have caused widespread ponderosa pine mortality throughout the west side of the Sierra Nevada. Ponderosa pine is also very susceptible to ozone damage.

The significant increase in ponderosa pine mortality over the past several years can be attributed to severe moisture stress, overstocking, and elevated western pine beetle activity. Mortality has occurred throughout the host range in scattered individual trees and in small groups of trees. This pattern of mortality over large acreages is difficult to quantify in terms of individual numbers of dead trees and volume associated with these trees.

Aerial surveys to detect conifer mortality were conducted on the Stanislaus and Sequoia National Forests during 1993. Results of these surveys indicate mortality levels to average about 3.6 trees/acre in the pine species (primarily ponderosa pine) and 3.7 trees/acre in fir species (primarily white fir). Aerial survey maps can be found in Appendix B.

Black stain root disease is scattered throughout the northern part of this section (see figure 4-9) and can be a predisposing agent to subsequent successful attack by western pine beetle. The most significant area with black stain root disease in this section is on the Georgetown Divide northeast of Placerville (Byler et al. 1979).



Ponderosa pine mortality caused by western pine beetle, Stanislaus National Forest.

Annosus root disease causes extensive mortality to conifers throughout California. Although the primary areas of mortality are in northeastern and southern California, the root disease can readily be found in many areas throughout the Sierra Nevada. Approximately 1.4 million acres of Jeffrey and ponderosa pine in California are infected with annosus root disease. An area of particular interest in this section is Yosemite National Park, where a survey conducted during 1970 found 102 annosus root disease centers in ponderosa pine and incense-cedar within the developed sites of Yosemite Valley. An additional 56 centers were confirmed in undeveloped sites (Marosy & Parmeter 1989).

Red fir

Red fir is found at high elevations (5,400 to 8,000 feet) throughout this section. At its lower elevational limit, it is found with white fir and other mixed conifer species. At higher elevations it is a component of mixed subalpine ecosystems. Moisture stress and fir engraver beetle have resulted in an increase in red fir mortality over the past several years. Fir engraver attacks can result in mortality, top-kill, or patch kills along the bole. Wood borers and other secondary insects are often found in trees infested with fir engraver beetle. Fir engraver beetles, windthrow and annosus root disease all contribute to the patchy distribution commonly found in red fir ecosystems.

Sugar pine

Sugar pine is a component of the mixed conifer type and is usually found above the 4000 to 5000 foot level. The most significant widespread disturbance agent affecting this species is white pine blister rust (see M261 Province discussion). In addition to this introduced pathogen, there are two native insects which are capable of causing tree decline and mortality. The mountain pine beetle attacks and kills sugar pine throughout the host range and occasional high populations of black pineleaf scale cause loss of needles, reduced growth and predispose trees to successful mountain pine beetle attack. Above normal levels of sugar pine mortality have occurred over the past few years throughout this section as a result of the protracted drought period and mountain pine

beetle activity. Most of the mortality has occurred as scattered individual trees, however, groups of up to 15 trees were killed during 1993 in Yosemite National Park.

An increase in the populations of black pineleaf scale on sugar pine during 1991-1992 resulted in many sugar pines with extremely thin crowns. Black pineleaf scale populations are normally kept at low densities by the scale's natural enemies, however when environmental conditions disrupt this balance, scale populations can reach damaging levels in localized areas. Although the recent infestation extended over a two year period and reduced the vigor of the heavily infested trees, most trees appear to have recovered and no mortality occurred as a result of the scale infestation alone.

White fir

White fir is found throughout this section as a component of the higher elevation mixed conifer ecosystems. It is also found in pure, or nearly pure stands, and mixed with red fir at its upper elevation limits. White fir dominates many ecosystems throughout this section that were once dominated by pine species. Fire exclusion and selection harvesting practices have caused a continued shift away from shade-intolerant pine species toward more shade-tolerant white fir. There are several insects and pathogens that affect white fir throughout its range. The primary insect is the fir engraver beetle. Douglas-fir tussock moth periodically causes defoliation and tree mortality in this section but populations are currently at low, non-damaging levels. Annosus root disease and true mistletoe affect white fir in localized areas throughout the host range.

Above normal levels of mortality and top-kill have affected individual trees scattered over thousands of acres throughout this section. This significant increase in white fir mortality is a result of severe moisture stress, fir engraver attacks and overstocking.

Years	Location	Acres of defoliation
1935-1937	Mono County	15,000
1954-1956	Calaveras & Tuolumne Counties	11,000
1963-1965	Modoc, Plumas, Lassen & El Dorado Counties	78,000
1970-1972	Amador, Calaveras, ElDorado, Fresno, Madera, Mariposa, Shasta, Tulare, & Tuolumne Counties	100,000+
1987-1989	Lassen, Plumas, Sierra, & Tehama Counties	105,000

Figure 4-11 -- Location and size of Douglas-fir tussock moth outbreaks in California, 1935-1989.

The Douglas-fir tussock moth (DFTM) is a native defoliator of conifers in western North America. White fir is the preferred host in California. There have been five major outbreaks of DFTM in California dating back to 1935 (Figure 4-11). In most areas, outbreaks have developed rapidly and then subsided after two years. Outbreaks in California have primarily occurred between the central and northern portions of the Sierra Nevada mountain range (Figure 4-13). Douglas-fir tussock moth may be viewed as having both positive and negative effects on the forest ecosystem, as well as on the resources and benefits derived from the forest (Clapp 1991).

Annosus root disease causes root decay and mortality of white fir throughout California, and can be a predisposing factor to successful fir engraver attack. Results of a survey conducted during 1979-1980 to determine the incidence of annosus root disease in 12 central and northern California National Forests estimated that 4% (1.46 billion board feet) of the live true firs were infected by *Heterobasidion annosum*, the pathogen which causes annosus root disease. Dead firs associated with the fungus were estimated to be 25% of the total dead firs during the 1.5 year period (Slaughter & Parmeter 1989).

True mistletoe in white fir is found in localized areas in the Sierra Nevada and in the mountains of southern California. It is considered to be a damaging agent, particularly where individual trees are of high value (i.e. campgrounds and other developed sites). Branches and tree tops that are heavily infected can break off and become hazardous in high use areas. This mistletoe is, for the most part, a parasite of larger and older trees. Many years are required for populations to build up and become damaging to white fir. In some instances, the parasite becomes so dense that tree tops and entire trees are weakened and die or are attacked and killed by fir engraver beetle.

Air Pollution

Certain forested areas in the Western United States are being significantly affected by air pollution. Ozone is, by far, the most common and damaging pollutant in California forests. In the 1960's, ozone was identified as causing a serious decline in the pine forests of the San Bernardino Mountains east of Los Angeles (Miller et al. 1963). Research field plots in southern California have been monitored since 1973.

In 1971, the first report of ozone injury to pines in the Sierra Nevada was published (Miller &

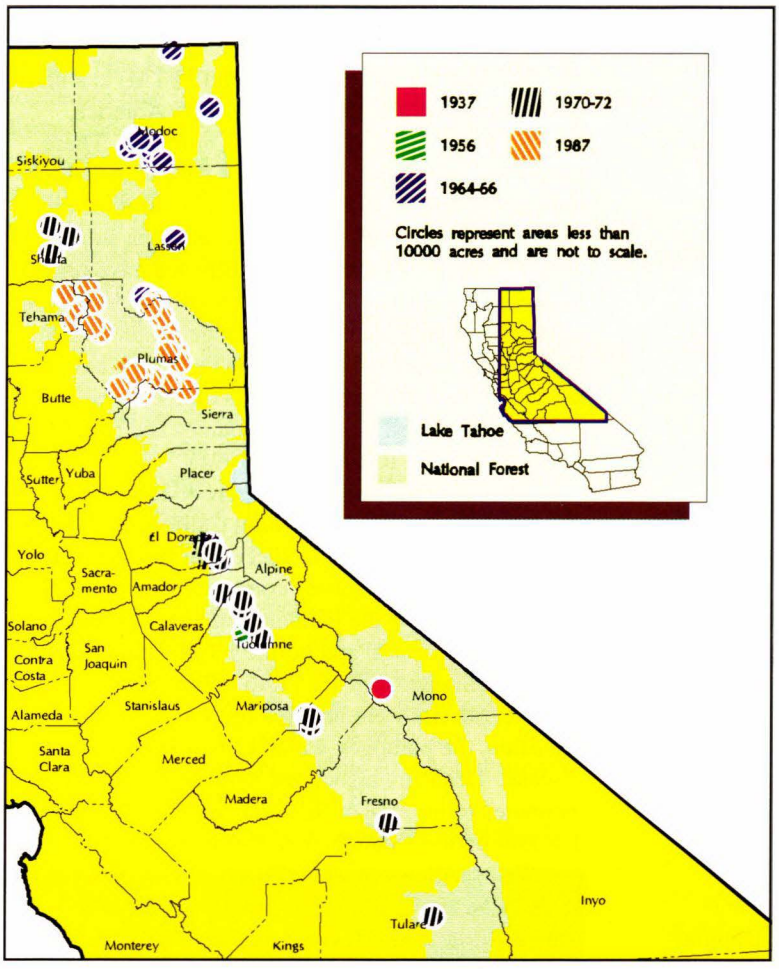


Figure 4-12 -- Areas of white fir defoliation by Douglas-fir tussock moth by outbreak period.

Millecan 1971). Most injury was found due east of Fresno in or near the Hume Lake Ranger District, Sequoia National Forest, and portions of Kings Canyon National Park. Since 1971, several studies have looked at the effect of ozone on the vegetation in the Sierra Nevada. Surveys based on foliar symptoms (chlorotic mottle) have documented that ozone injury is present throughout most of the Sierra Nevada with a gradient of increasing injury from north to south.

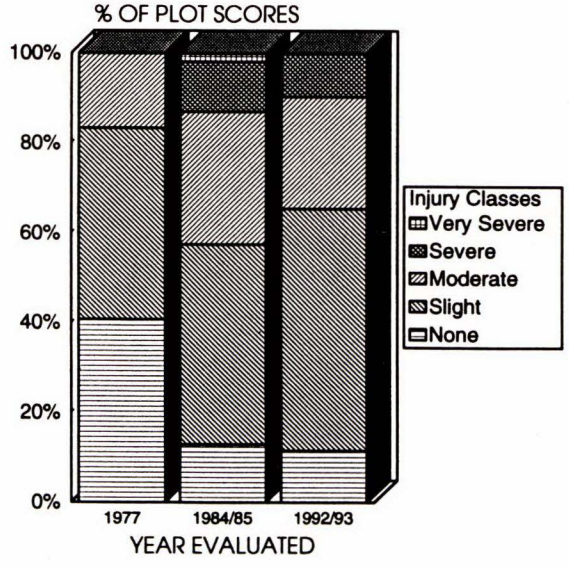
A set of 54 ozone injury trend plots on the Sierra and Sequoia National Forests have been revisted biannually since 1977 (Pronos & Vogler 1981). The trend plot network showed a fairly obvious increase in visible ozone injury between 1977 and 1984, after which injury remained fairly constant. During the late 1980's and early 1990's, which corresponded to a prolonged drought period, visible injury slowly decreased (figure 4-13).

On a forest-wide basis in the Sierra Nevada, the effects of ozone on tree growth are unclear. One dendrochronology study found no significant growth effect (Peterson et al. 1991), while another reported an 11% reduction in growth (Peterson et al. 1989.) Available moisture and competing vegetation have a far more powerful effect on tree growth than ozone at the levels experienced in the Sierra Nevada.

Current Forest Health Activities

Jeffrey pine beetle suppression projects were initiated in the Lake Tahoe Basin during 1983. Infested Jeffrey pine trees were removed on an annual basis for 4 consecutive years (1983-1987) over 165 acres in an effort to directly control the Jeffrey pine beetle to subsequently reduce future mortality. Jeffrey pine beetle-related mortality in the treated area declined from 330 trees in 1983 to 4 trees in 1987, a 99% reduction. Currently, Jeffrey pine beetle suppression is being conducted in the Nevada Beach Campground (60 acres) and the Zephyr Cove Resort (45 acres) on the east shore of Lake Tahoe. In May-June, 1993, 116 infested trees were removed from Nevada Beach and

Figure 4-13 -- Changes in ozone injury trend plot scores in the southern Sierra Nevada, 1977-1993.



tively, in the number of Jeffrey pine attacked by the 1993-1994 generation of beetles. The U. S. Forest Service intends to continue suppression activities for Jeffrey pine beetle in the Lake Tahoe Basin in 1994 and beyond as appropriate (Wenz 1993).

In addition to aerial sketch map surveys, the Pacific Southwest Region, U. S. Forest Service, is also exploring other cost-efficient and effective methods to accurately determine levels of conifer mortality. A cooperative agreement between Boston University, Region 5 of the U.S. Forest Service and the Lake Tahoe Basin Management Unit was developed to evaluate the potential of using satellite remote sensing to inventory conifer mortality associated with 6 years of drought. A canopy reflectance model for comparing stand structure between the Landsat Thermatic Mapper imagery of 1988 and 1991 were used. The results of the analysis provided an estimate of timber volume loss on the LTBMU due to conifer mortality during 3 years of drought and illustrated the ability to use satellite remote sensing to inventory conifer mortality (Macomber & Warbington 1993). The LTBMU change detection map can be found in Appendix A.

As part of a regional effort to maintain a viable population of rust resistant sugar pine throughout its natural range, many National and State Forests have adopted preventative spray programs to protect trees from successful mountain pine beetle attacks. Carbaryl is sprayed directly on the rust resistant sugar pine trees and on adjacent trees within a 30 foot radius. National and State Forests which have conducted prevention spraying projects include the Tahoe and Stanislaus National Forests and Mountain Home Demonstration State Forest. In addition to preventative spraying, silvicultural techniques aimed at removing competing vegetation are also being implemented to promote the growth and vigor of these trees.

Several projects with the objective of reducing bark and engraver beetle-related mortality have been ongoing throughout the Sierra Nevada ecological section for many years. National Forests in this ecological section with recent or current bark beetle prevention thinning projects, which have been partially funded by Forest Pest Management Prevention/Suppression funds, include the Sierra and Stanislaus National Forests and the Lake Tahoe Basin Management Unit. Cooperative bark beetle pheromone research between Forest Pest Management and

Year	Total			NUMBER OF PLOTS WITH AN AVERAGE MOTH CATCH PER TRAP OF:											
	Number														
	Plots	0<10	10<20	20<25	25<30	30<35	35<40	40<45	45<50	50<55	55<60	60<65	65<70	70<75	75+
1979	102	97	2	1	1	0	1	0	0	0	0	0	0	0	0
	100%	95%	2%	1%	1%		1%								
1980	99	99	0	0	0	0	0	0	0	0	0	0	0	0	0
	100%	100%													
1981	93	78	10	4	1	0	0	0	0	0	0	0	0	0	0
	100%	84%	10%	4%	2%										
1982	95	93	1	0	1	0	0	0	0	0	0	0	0	0	0
	100%	98%	1%		1%										
1983	98	87	6	1	1	3	0	0	0	0	0	0	0	0	0
	100%	89%	6%	1%	1%	3%									
1984	111	51	18	11	5	7	8	4	3	4	0	0	0	0	0
	100%	46%	16%	10%	4%	6%	7%	4%	3%	4%					
1985	105	58	14	4	7	6	5	1	2	4	1	2	0	1	0
	100%	55%	13%	4%	6%	6%	5%	1%	2%	4%	1%	2%		1%	
1986	107	64	16	4	8	6	1	3	0	1	0	1	1	1	1
	100%	60%	15%	3%	7%	6%	1%	3%		1%		1%	1%	1%	1%
1987	108	80	15	4	2	1	1	3	0	1	0	0	1	0	0
	100%	74%	14%	4%	2%	1%	1%	2%		1%			1%		
1988	124	106	9	3	3	0	2	1	0	0	0	0	0	0	0
	100%	86%	7%	2%	2%		2%	1%							
1989	130	129	1	0	0	0	0	0	0	0	0	0	0	0	0
	100%	99%	1%												
1990	138	135	1	0	1	1	0	0	0	0	0	0	0	0	0
	100%	97%	1%		1%	1%									
1991	143	135	4	1	0	0	2	1	0	0	0	0	0	0	0
	100%	94%	3%	1%			1%	1%							
1992	164	156	3	0	2	1	0	0	0	0	1	0	1	0	0
	100%	95%	1%		1%	1%					1%		1%		
1993	143	135	8	0	0	0	0	0	0	0	0	0	0	0	0
	100%	94%	6%												

Figure 4-14 -- Douglas-fir tussock moth early warning detection trap plot results for California, 1979-1993.

Stanislaus National Forests and the Lake Tahoe Basin Management Unit. Cooperative bark beetle pheromone research between Forest Pest Management and the Pacific Southwest Research Station is continuing in an attempt to use pheromones to minimize bark beetle-related resource damage.

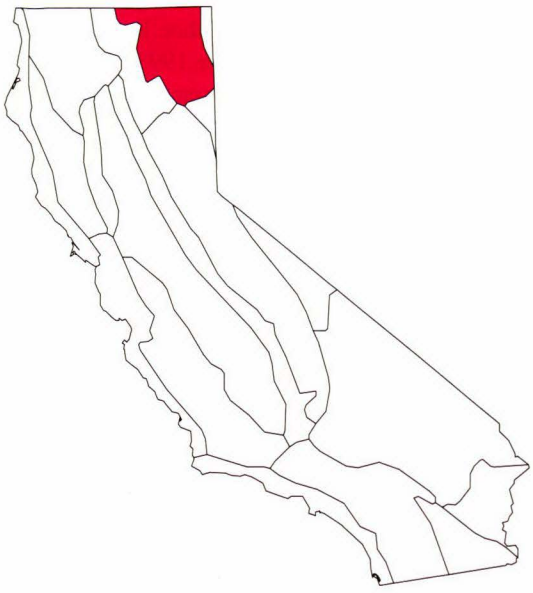
Several experimental and operational control projects have occurred during the major DFTM outbreaks. A network of DFTM early warning detection trap plots have been established and are monitored annually throughout the Sierra Nevada and northeastern California. These traps monitor DFTM population levels within localized areas. The results of the survey from 1979-1993 are included in Figure 4-14.

There has been one recent suppression project and one recent pre-suppression survey completed to minimize the impacts of dwarf mistletoe in this section. A dwarf mistletoe suppression project was completed over 20 acres in the Twin Lakes campground on the Inyo National Forest during 1993. This project involved both pruning and tree removal. A pre-suppression survey was conducted over 9,200 acres on the Groveland Ranger District, Stanislaus National Forest. Management options are currently being considered to minimize the impacts of dwarf mistletoe on the vegetation and on the resource management goals for these areas.

An annosus root disease suppression project was completed in the Shady Rest Campground on the Inyo National Forest during 1993 which involved reinforcement of buffer zones and removal of infected stumps. An annosus root disease pre-suppression survey was completed during 1993 at the Tallac Historic Site, Lake Tahoe Basin Management Unit. Currently, a plan is being developed for the long-term management of this high-value historic site. It is Forest Service policy throughout the National Forests in California to treat all recently cut conifer stumps with borate compounds in developed recreation sites.

Several networks of ozone monitoring plots exist in the Sierra Nevada. In addition to the 54 trend plots previously mentioned on the Sequoia and Sierra National Forests, 24 similar plots were established in the Lake Tahoe basin in 1987 and were revisited in 1993 (Pedersen 1989). Project FOREST (Forest Ozone REsponse STudy) is a joint venture involving the USDA Forest Service, USDI National Park Service, and California Air Resources Board that began monitoring ambient ozone levels and nearby injury to pine vegetation in 1991 on 5 National Forests and 4 National Parks in the Sierra Nevada.

M261G Modoc Plateau



Ecology

This section of California has characteristics common to the Southern Cascade and Northern Sierran sections, and the Great Basin. Mountains and ridges with intervening basins often provide for sweeping vistas that include remnant lake beds, shield volcanoes, cinder cones and lava flows. The basins and fractured nature of the landscape provide for a small number of slow flowing rivers and many slow to moderately rapid flowing streams, most of which are intermittent. Dominant mountain ranges are the Warner, Adin, and Big Valley Mountains.

The climate is harsh, cold and dry. Elevation (3,000 to 9,900 feet), precipitation (12 to 30 inches per year), and temperature (means from 45 to 52°F) combinations produce vegetation that is variously dominated by ponderosa and Jeffrey pine, mixed conifer, western juniper woodland savannah, and big and low sagebrush. Juniper covers the largest block of type in the section, followed by ponderosa and Jeffrey pine and mixed conifer. The diversity of tree species is generally less than in many other areas of the state. In addition to the dominant species, other tree species are: Washoe pine (a high-elevation relative of ponderosa that is found in the South Warner Mountains), incense-cedar, lodgepole pine, western white pine, whitebark pine and aspen, with red fir, knobcone pine, and sugar pine at some locations near the border of the section.

Before the beginning of settlement of the plateau in about 1850, pine stands were relatively open

"parklike" stands that sometimes contained a mix of other conifers. Undergrowth generally consisted of perennial bunchgrasses and relatively few shrubs. These characteristics were maintained by low intensity ground fires. Beginning in the 1880's, logging, fire suppression and livestock grazing have altered eastside pine communities to more densely stocked stands of smaller diameter trees with higher canopy closures. White fir encroaches from higher elevations, and western juniper encroaches on lower, drier sites (Laudenslayer et al. 1990).

Forest Health Issues

Ponderosa pine

Ponderosa pine is found in pure stands or in combination with Jeffrey pine or invasive white fir. These stands are often overstocked, which creates stress conducive to opportunistic attacks on ponderosa pine by the western pine beetle or the mountain pine beetle. Mountain pine beetle also attacks sugar pine and lodgepole pine and may have more overall impact than western pine beetle on the combined pine resource of the section. Forest Pest Conditions reports from 1945 to 1992 feature the mountain pine beetle more commonly than the western pine beetle. This may well be the only region of the state where this is true. The mountain pine beetle is more common in ponderosa pine in this section than elsewhere in the state. Perhaps this can be related to the characteristic that, ".... these `eastside' ponderosa pines are often morphologically and physiologically different from those of the main California distribution" (Haller 1962). Mortality in very dense stands of saplings and small poles often is attributable to the mountain pine beetle.

Fluctuations in mortality associated with the two beetles frequently vary in parallel because similar stresses produce similar opportunities for attack. Cycles of increases in mountain pine beetle seem to last longer, eg. 1955 to 1964 when mountain pine beetle was chronic in lodgepole pine and second-growth ponderosa pine. Ten years later mountain pine beetle was back in the same lodgepole pine area. It may have taken the intervening 10 years to rebuild the stocking to levels inducing host stress.

To this complex of western pine beetle and mountain pine beetle can be added the red turpentine beetle, the California flatheaded borer, and pine engravers, which frequently are found in the same pines. These additional species often attack parts of the tree where the others are not found, eg. red turpentine beetle in the root collar/stump area and the engravers in the top and branches. Thus, the tree resource is often partitioned by the various attacking insects.

Western dwarf mistletoe can be commonly found in some areas, particularly on sites of lower quality. Where present, this parasite contributes to growth loss and mortality by draining the host of needed water and minerals. This becomes particularly important when drought decreases available soil moisture. Smith (1983a) rates dwarf mistletoe as the most damaging disease in the eastside pine type. Surveys from 1958 to 1966 indicated about 9% of the ponderosa and Jeffrey pines were infected. Yet in the drought of 1976-1977, 75% of the pines killed from June 1976 to June 1977 were killed by a complex of dwarf mistletoe, bark beetle and/or flatheaded borer. After the drought had peaked and ended, dwarf mistletoe was still involved in 42% of the mortality (Smith 1983a).

The root disease that dominates management strategy in the eastside pine type is annosus root disease, which was first reported in the 1930's from an area just north of the town of Westwood. Unfortunately, this root pathogen is widespread in eastside pine, often is associated with past harvesting practices that occurred without the treatment of cut surfaces with borax, and it remains persistent and aggressive for several decades once introduction occurs. Surveys on the Lassen National Forest have shown 6% to 84% of pine stumps infected (Estes & Dieter 1977). Byler et al. (1978) found 60% of stumps infected on the Fletcher Sale on the Devils Garden District, Modoc National Forest, and surveys of ten 8 to 15 year old sale areas by Kliejunas (1986) showed 50% infection (range 20 to 80%). Twenty percent of each acre surveyed was out of production. Six sale areas on the Modoc and Lassen National Forests where stumps were treated with borax had 0 to 4% infection rates, and two non-boraxed sale areas on the Modoc had stump infection rates of 23 and 70% (Kliejunas 1989). These rates are conservative because only stumps with conks were counted and stumps could be infected without visible signs. Similar infection levels have been found in the Oregon portion of the province (Goheen & Goheen 1989).

With few tree species other than pines well adapted to many sites, infection centers present a long-term management problem. However, aggressive early-age thinning of natural stands along with diligent treatment of stumps with borate has been effective in minimizing root-to-root spread as well as the establishment of new infection centers.

Black stain root disease in the section (Figure 4-8) is common in ponderosa and Jeffery pine stands.

This is true in overstocked stands where stress from competition and site disturbance may provide hosts susceptible to insect vectors of the fungus (Kliejunas 1992). Pines that have invaded moist areas such as meadows may also be more prone to infection. Stress from black stain root disease may likely lead to attack by bark beetles such as the western pine beetle and the Jeffrey pine beetle.

Jeffrey pine

Jeffrey pine is mixed in with ponderosa in parts of the section. Mortality from Jeffrey pine beetle over the past 50 years generally has been scattered and at low levels and not a major health concern. The early1940's were low mortality years, with some increase in mortality from 1946 to 1952. Mortality levels remained low until 1961. In 1963, 3.5 million board feet of timber was killed -- over 22,000 acres -- in the South Warner Mountains. Losses were noted again in 1966, but effects on the Jeffrey pine resource remained minor after that time. Only state conditions reports of 1980 and 1992 mention the Jeffrey pine beetle in the section, with the latter report confined to trees of the mature age class.

White fir

White fir is the only true fir in most of the section, and the only fir of the Warner Mountains. Because of fire suppression and removal of pine, white fir has invaded many sites previously dominated by pine. These trees survive until overstocking, age and drought make them highly susceptible to successful attack by the fir engraver. Mortality under these conditions can become quite high with as much as 80% of the stand volume affected. Such was the situation in 1993.

Mortality levels of white fir have undergone dramatic swings in this section. During the 1950's fir mortality was generally low or unreported. Precipitation fell well below average from 1959 through 1962. Mortality increased to "heavy losses" by 1962. A low period occurred from 1963 through 1965. In 1967 and 1968, fir engraver activity increased in areas where Douglas-fir tussock moth had been in outbreak in 1964. The fir engraver was not again prominently featured in reports until the drought of 1977 when, in the following few years, roundheaded fir borer was an agent of mortality along with the fir engraver. True fir stands were not significantly affected again until top and branch kill increased in 1989 and scattered mortality appeared in locales along the western boundary of the section. This mortality was associated with drought, root disease, dwarf mistletoe and cytospora canker. Fir mortality remained low in succeeding years while heavy mortality could be found in many other areas of California. This began to change in 1992 when heavy mortality began to appear. The effect of the six-year drought of the late 1980's and early 1990's finally struck true fir stands and the fir component of the mixed conifer.

White fir is also attacked by a number of other insects and pathogens. The Modoc budworm is a defoliator of white fir unique to this section that is frequently in outbreak somewhere in the Warner Mountains (Figure 4-15). Outbreaks have varied in duration and intensity. Review of Forest Pest

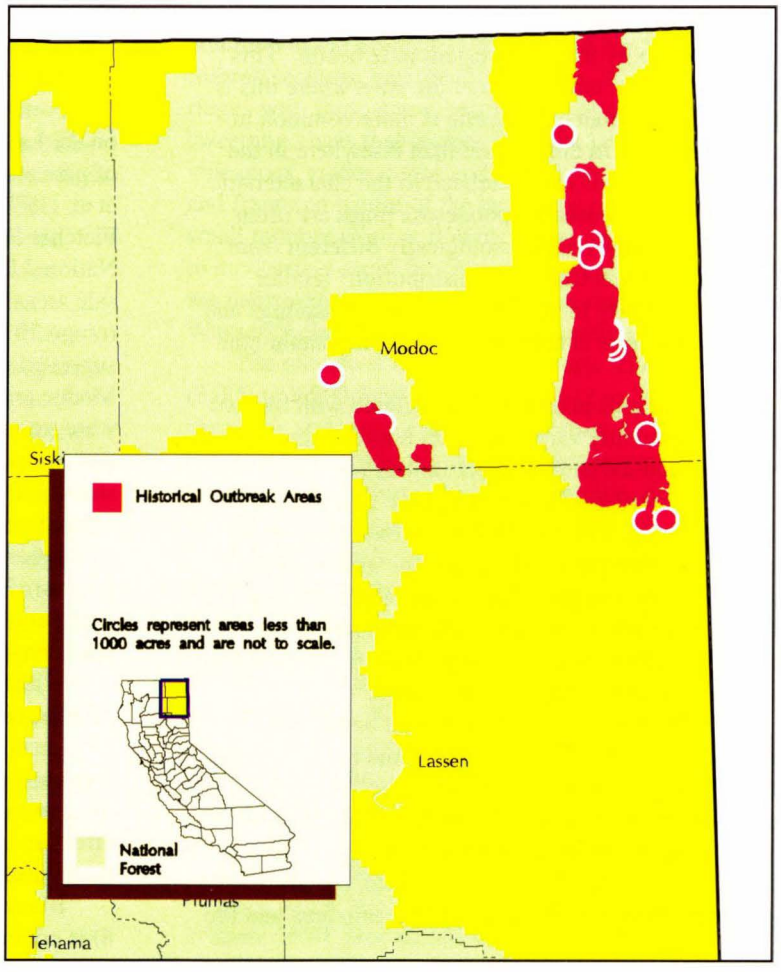


Figure 4-15 -- General areas of white fir defoliation by the Modoc budworm in northeastern California.

Condition Reports indicates that defoliation was persistent through much of the 1940's into the early 1950's, and light from 1953 to 1955. In 1973 and 1974 a sudden outbreak surged across 160,000 acres only to collapse in 1976. In 1985 slight to heavy defoliation was observed, with a peak of 50,000 acres affected by 1986. Visible defoliation declined over the next two years to 25,000 and then 20,000 acres, to no visible defoliation in 1989. This decline was temporary, for 80,000 acres were recorded in 1992, and this declined to 30,000 acres of visible defoliation in 1993. Growth loss has occurred during these episodes, but little mortality can be attributed to this defoliator. However, the defoliation is one more stress leading to increased susceptibility to successful attack by the fir engraver.

Population surges of the white fir sawfly also seem to be more frequent in this section than in other areas of California. Reports of defoliation have centered about the periods 1955-1956, 1963-1964 (25,000 ac), 1970-1972, 1985 and 1992. Defoliation in 1985 and 1992 coincided with outbreaks of the Modoc budworm. In 1963 the sawfly was found along with an outbreak of Douglas-fir tussock moth on white fir that peaked at 59,730 acres at Knox Mountain, 470 acres at Stowe Reservoir, and 2,280 acres at Roney Flats (Modoc County). By 1965, only 600 hundred acres of Douglas-fir tussock moth defoliation was found at Corral Creek. Early warning trapping has indicated possible increases in Douglas-fir tussock moth within the section, but no outbreaks have occurred since the 1960's.

White fir also is host to a number of pathogens. Annosus root disease is commonly found in white fir stands regardless of their previous logging history (Schultz 1980). However, the number of entries into a fir stand for tree removal does make a difference in infection levels and the average percentage of white fir infected and killed (Goheen & Goheen 1989). In white fir, unlike pine, the pathogen acts primarily as a root and butt rot. Should drought, overstocking, or other stressors cause additional root loss, decline and mortality are likely. Invasion of fir into drier pine sites accelerates decline and these fir frequently do not reach maturity.

Dwarf mistletoes are found in white fir and cause stress, growth loss, and open wounds on boles. Trees with dwarf mistletoe are susceptible to cytospora canker and are frequently some of the first firs attacked by the fir engraver when droughts and other stressors occur.

Five-needle pines

Sugar pine, western white pine, and whitebark pine occur in the section. All are susceptible to white pine blister rust, first reported from within the section in state reports in 1956 at Whitehorse. It was first found on western white pine in the Warner Mountains in 1985. All three species are attacked by the mountain pine beetle. Even though these species are a minor forest component, losses without replacement would lead to a decline in forest biodiversity.

Juniper

Western juniper dominates the northern juniper woodland that covers more acres in the section than the pine type. It "has replaced the grass/shrub vegetation on large acreages at the lowest elevational margins of the eastside pine type as a result of livestock grazing and fire suppression" (Laudenslayer et al. 1990). At present, it appears that insects are having little effect upon this resource. However, juniper is susceptible to annosus root disease, which can spread through infected pine stumps to infect adjacent junipers. Recent changes in the acres of type are mostly anthropogenic, but the region is sparsely populated and these effects have been minor.

Current Forest Health Activities

Many stands in the section are heavily infected with dwarf mistletoe. The method by which the parasite moves from tree to tree limits its spread. Stands that are predominantly pine are being thinned to remove heavily infected trees and to increase the distances between the remaining trees, which reduces the probability of spread. Plantations with dwarf mistletoe-infected white fir have been thinned to improve tree growth. In mixed species stands, thinnings are manipulated to create barriers of nonhost trees as well as increase the distance between trees. This takes advantage of the host specificity of many dwarf mistletoe species. In stands of mixed ages, older or taller infected trees are removed to prevent the infection of the younger, understory trees. As these trees age, they in turn will be less susceptible to drought and other stresses.

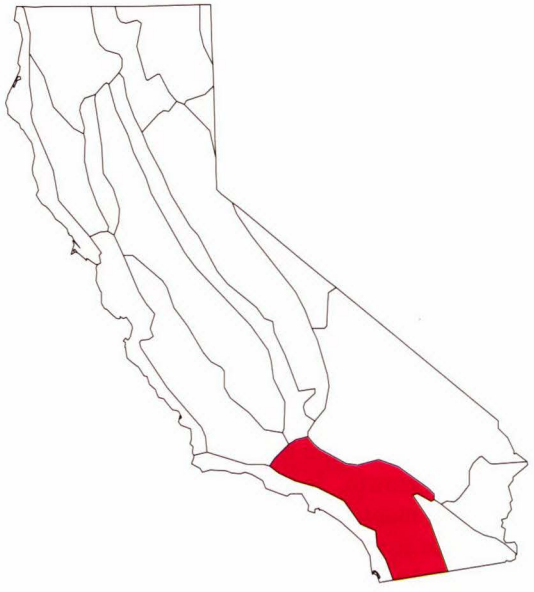
Thinning also is a useful tool in reducing intertree competition and removing trees unsuited to the site. In this section this usually means invasive white fir. By lessening the competition on residual trees, they are better able to resist bark beetle attack when other forms of stress occur. This has been well illustrated at the Demonstration Thinning Plot in the Eastside Pine Type, Lassen National Forest (California Forest Pest Council 1993).

Annosus root disease represents a management problem in many parts of the section. Most freshly cut stumps of live conifers are treated on the cut surface with a borate formulation to prevent infection and spread to surrounding trees. The spread and intensification of the disease in this section is presently under examination through the use of a computer model.

M262 CALIFORNIA COASTAL RANGE, OPEN WOODLAND, SHRUB, CONIFEROUS FOREST, MEADOW PROVINCE

M262A -- Please refer to M261C

M262B Southern California Mountains and Valleys



Ecology

This section lies to the north and east of the major urban centers of southern California. North to south, the dominant topographical features are the ranges and valleys of the Tehachapi, San Gabriel, San Bernardino, San Jacinto and Santa Ana Mountains, and small ranges southward to the Mexican border. These mountains are steeply sloping to precipitous and high peaks have unstable slopes and sharp crests. Valleys tend to be narrow. Characteristic features are elevation - ranging from 500 to 11,500 feet; precipitation - 10 to 40 inches; mean temperatures - 45 to 64°F; and growing season - 100 to 200 days. Winters can be wet, but April through October is usually dry. Earthquakes can modify slope topography, and fire, the vegetative cover. Urban development and numerous exotic plant species are modifying land use patterns.

Forests within the section appear on north-facing slopes and wetter sites. Major conifer species are ponderosa pine, white fir, Jeffrey pine, Coulter pine, sugar pine, incense-cedar, singleleaf pinyon pine, and bigcone Douglas-fir. Major hardwoods are California black oak, canyon live oak, interior live oak, and Engelmann oak. In general, the proportion of the area now supporting conifer forests appears to be approximately what it was in 1900 (McKelvey & Johnston 1992). However, private forest lands have been frequently modified by residential and commercial development.

At the turn of the century, low-elevation forests of the section were dominated by either ponderosa pine or bigcone Douglas-fir. Bigcone Douglas-fir may have been once more abundant prior to increases in fire frequency associated with human activity in the later 19th century. White fir was a major component above 6,000 ft and lodgepole pine occurred mostly above 8,500 ft. The mountain ranges were extensively grazed by sheep prior to 1900, but intensity and impacts may have been overstated (McKelvey and Johnston 1992). Significant timber removal occurred in the San Bernardino Mountains in the late 1800s. Since then, the period of greatest timber removal in the section came after World War II, particularly from 1954 to 1977.

Forest Health Issues

Ponderosa and Coulter pines

Periods of high mortality of these pines have been observed in southern California for at least the past eight decades. As early as 1949, mortality was attributed to a "complex" of climate, disease and insects (FICC 1949). To this complex could have been added inter- and intraspecific vegetative competition.

Epidemic infestations of the western pine beetle and pine engravers have repeatedly caused severe mortality at some locations in southern California. Various combinations of the Corte Madera, Julian, Cuyamaca, Palomar and Laguna areas of San Diego County experienced impressive tree mortality during 1946-1949, 1958-1963, 1966, 1968, 1985, and 1989-1992. Outbreaks have also been frequent in the Arrowhead-Crestline area and other locations in the

San Bernardino and San Jacinto Mountains of San Bernardino and Riverside Counties.

Annosus root disease is frequently associated with areas of high mortality of pine. As early as 1941 a "root fungus" was contributing to the death of pines marked for treatment in a bark beetle control program on Laguna Mountain, San Diego County (Wagener & Cave 1946). More recent work indicated that annosus root disease was responsible for 48% of the pine mortality on Laguna Mountain (Wood et al. 1979). On the San Bernardino National Forest, annosus root disease was associated with 10% of the Coulter pine mortality from 1976 to 1978 (Smith & Roettgering 1982). A later survey on the same forest found this root disease associated with 18% of the Coulter pine that died in 1981-1982 (DeNitto & Pierce 1983). Whether high infection rates are endemic to these mountains or a product of human activity (bark beetle control projects prior to the use of borax as a preventative stump treatment) is uncertain.

Pine forests in this section are frequently infected with dwarf mistletoes. Heavily infected trees die prematurely when other stresses such as drought occur. Drought stress was severe in 1981-1982 when dwarf mistletoes were part of the complexes that killed 65% of the number and 46% of the volume of Coulter pines affected (DeNitto & Pierce 1983). In the better, but still subnormal precipitation period of 1976-1978, dwarf mistletoes were involved in 22% of the Coulter pine mortality (Smith & Roettgering 1982; DeNitto & Pierce 1983).

In areas undergoing residential and commercial development, local tree mortality has been abetted by mistakes in vegetation management connnected with home construction and development. Much of this mortality could be avoided with foresight and appropriate management techniques (Koehler et al. 1983).

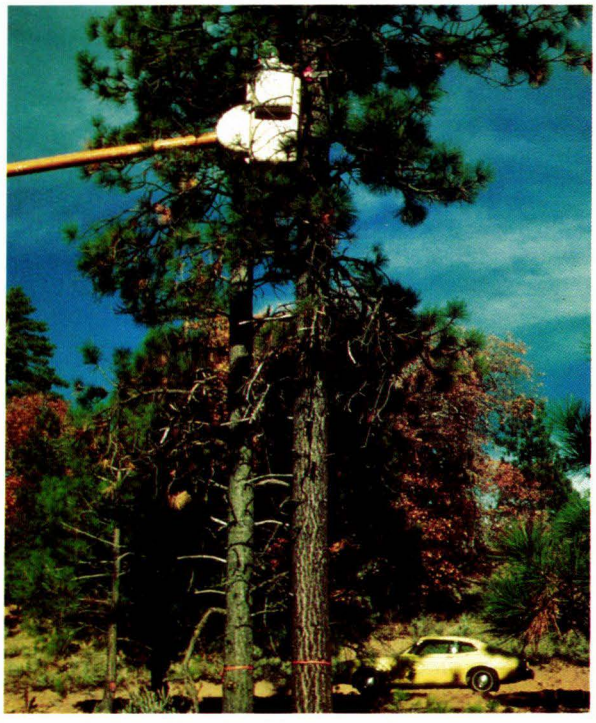
Jeffrey pine

Mortality of Jeffrey pine in San Bernardino and San Diego Counties has been recurrent. Years of increased mortality from the Jeffrey pine beetle were 1949, 1957-1958, 1966-1967, 1970-1972, 1979-1983, and 1987 to 1988. The Jeffrey pine resource also has been subjected to repeated damage by the activity of the California flatheaded borer. This woodborer is common on Jeffrey and ponderosa pines throughout the state, but has its greatest impact in southern California, where some consider it to be the most important tree-killer. It is the nature of the life cycle that larvae may be in place under the bark for several years before moisture stress or some other environmental factor allows them to grow rapidly and kill their host. This rapid response can make the insect a major cause of mortality during sharp, short droughts such as the one of 1981-1982 on the San Bernardino National Forest (DeNitto & Pierce 1982).

Infections of dwarf mistletoe and/or the annosus root disease pathogen are frequently associated with attacks by the California flatheaded borer. High or epidemic losses occurred at one or more locations in the section all through the 1950s. By 1962, mortality from flatheaded borers was decreasing and from 1963 to 1965 only forested areas of Riverside County reported notable losses. In 1976, 61% of the mortality was attributed to complexes involving flatheaded borers plus annosus root disease and/or dwarf mistletoe (Byler et al. 1977). This figure dropeds to 52% for all of 1976-1977 (Smith & Roetterging 1982). During 1981-1982, this combination accounted for 49% of Jeffrey pine mortality. Losses were again high in 1988-1990.

At certain limited locations in the San Bernardino Mountains, Jeffrey pine has been subject to attack by the Jeffrey pine needleminer. Although not a tree-killer, the needleminer can induce stress creating favorable host condition for the Jeffrey pine beetle

Dwarf mistletoe witches' brooms severely affect pine growth and longevity. Pruning witches' brooms is a management tool used in recreational areas to prolong tree life and maintain vegetative cover. Campground on the Cleveland National Forest.



and the California flatheaded borer. The most significant infestation lasted from 1972 to 1985 when up to 3,000 acres at Big Bear Lake were infested. Parts of this area are becoming increasingly subdivided and developed, and the effect of this on the host-insect relationship is not known. The effects of urbanization on the host may surpass the impact of the needleminer.

White fir

The white fir resource in southern California is primarily damaged by drought, the fir engraver beetle, annosus root disease and true mistletoe. Damage by the fir engraver is often connected with drought. High losses were reported in 1952, 1976-1977, 1982, and 1989-1991. Beetles were involved in 87% of the white fir mortality in 1976 (Byler et al. 1977) and 96% of the mortality for 1976 and 1977 combined (Smith & Roettgering 1982). During 1981-1982, beetles were again associated with 96% of the mortality. Top-kill is also quite common and multiple top replacement gives older trees a "candelabrum" appearance.

True mistletoe replaces dwarf mistletoe in southern California as an important factor in white fir mortality. In 1976, true mistletoe was found in 25% of the mortality and 20% for 1976 and 1977 combined. A similar figure of 27% was found in 1981-1982. Top-kill also is often associated with infections of true mistletoe in tree tops. Although primarily a water parasite, true mistletoe appears to stress tops sufficiently during droughts to favor fir engraver and other bark beetles.

White fir infected with the pathogen causing annosus root disease can appear quite healthy under conditions favorable to growth, but drought and infection by true and/or dwarf mistletoes can lead to rapid decline and attack by fir engravers. Seventy-four percent of the white fir that died in 1976-1977 had root disease as part of the mortality complex (Smith & Roettgering 1982). A similar survey during 1981-1982 found that 36% of the number and 46% of the volume of dead white firs had root disease (DeNitto & Pierce 1983).

Singleleaf pinyon pine

Singleleaf pinyon pine in this section is attacked by a strain of the pathogen causing black stain root disease. First reported in Southern California in 1958, infection centers on the east side of the San Bernardino Mountains form mosaics of infected/uninfected patterns over as much as 7,800 acre units.

Pinyon pines weakened by black stain are favored hosts of the pinyon pine ips. The most recent upsurge in mortality from this engraver beetle occurred in 1991-1992.

Stands of singleleaf pinyon pine on the San Bernardino National Forest have large opening without vegetation because of black stain root disease.

California black oak

Large portions of forested private lands within the section have substantial amounts of black oak and have been developed for summer or year-around residential use. An area around Lake Arrowhead was affected by an outbreak of fruittree leafroller from 1974 to 1986. During this period defoliation varied from 2,000 to 25,000 acres. Defoliation leads to dieback amd sometimes mortality, and continued stress could lead to oak mortality from armillaria root disease. This disease is usually associated with oaks, but healthy oaks can coexist with the pathogen. However, defoliation, installation of lawns with subsequent overwatering, soil compaction, substantial root injuries and other stressors can provide this root disease the opportunity to damage and even kill black oak.

Engelmann oak

The main distribution of this species lies in western San Diego County, usually below 4,000 feet It also occurs as a dominant on the Santa Rosa Plateau in Riverside County. As such, its range lies outside public lands and incorporates extensive urban development and potential development. This is the primary threat to the health of this forest species. Land purchases by conservation groups and cooperative agreements with developers should mitigate some of the inevitable decline of this plant community.

Air pollution

A decline in the vigor of ponderosa pine was reported in the 1957 California Forest Pest Conditions Report for the Arrowhead-Crestline area in the

San Bernardino Mountains. This decline appeared to be spreading. As the pines yellowed and lost their complement of older needles, they became more susceptible to attack by bark beetles and flatheaded borers. Subsequent research on the "X disease" attributed the damage to air pollutants, primarily ozone, carried by prevailing winds into the mountains. Implementation of air pollution control measures since that time have resulted in a visible improvement in crown condition since the late 1980's. Many of the more ozone-sensitive ponderosa and Jeffrey pines died in the interim.

Current Forest Health Activities

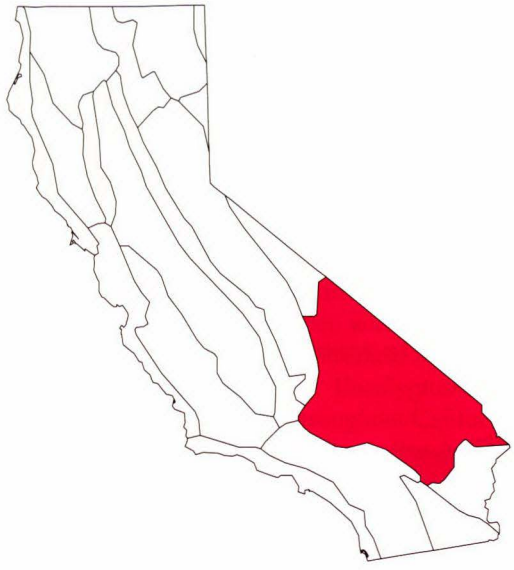
Many of the campgrounds in the coniferous forests of southern California have lost trees from various insect/disease/pollution complexes. Much of the effort to maintain or enhance forest health has taken place in campgrounds to mitigate losses. Dwarf mistletoe brooms and plants have been pruned from pines to decrease the moisture and nutrient drain and thus increase the longevity of the trees. Trees and plants less susceptible or resistant to annosus root disease have been planted to replace losses caused by the root disease/bark beetle complex. At least one site has been trenched and stumps pulled to ascertain whether such procedures would reduce the incidence of the disease and its longevity in the soil. Stands and clumps of trees have been thinned to reduce inter-tree competition and thereby stress. Species of trees and selections from local populations have been tested to find sources of pines resistant to ozone. But more importantly, air quality in urban areas has improved and this has reduced exposure of trees to debilitating pollution levels.

Some of these measures also have been applied in general forest areas. Stands and plantations have been thinned to reduce the presence and impact of dwarf mistletoe. Thinning has been used to regulate vegetative competition and reduce tree susceptibility to attack by bark beetles during periods of soil moisture stress.

Areas of black stain root disease in pinyon pine stands have been delineated and these areas are being studied to ascertain means whereby the disease can be manipulated and its effects mitigated.

322 AMERICAN SEMI-DESERT AND DESERT PROVINCE

322A Mojave Desert



Ecology

The Mojave Desert section is the largest section within this province and occupies part of southeastern California, southern Nevada and northwestern Arizona. Its geomorphology is described as desert plains with isolated mountains, plateaus, alluvial fans, playas, basins and dunes. Precipitation ranges from 3 to 10 inches and occurs as scattered high intensity storms of short duration. Seasonal water flows into the alluvial channels and terminate in the basins within this section. Mining, grazing, military testing, recreational activities and rapidly expanding urbanization have altered many of the ecosystems in this section. Fire does not play a dominant role in these ecosystems because average rainfall levels do not support enough vegetation.

The vegetation on the basins, plains and hills consists of creosote bush, blackbush, greasewood and saltbush. Hardwood species such as cottonwood, salt cedar and Palo Verde are found in the riparian areas around the Colorado river. On the alluvial fans at the desert edge California juniper and Joshua trees are found. Singleleaf pinyon pine and Utah juniper occur in woodlands in the mountains. White fir is found at the higher elevations in the mountains between 6,000 and 7,000 feet.

Figure 4-16 -- Known locations of black stain root disease infecting singleleaf pinyon pine in California.

Forest Health Issues

Singleleaf pinyon pine

Single leaf pinyon is a slow growing, long-lived pine which occurs in pure stands or with juniper on mountain slopes, foothills, and canyons ranging from 2,100 to 7,800 feet elevation. Black stain root disease is the most important pathogen affecting singleleaf pinyon in the Mojave Desert section (Figure 4-16). It is suspected that this root disease in singleleaf pinyon is vectored by beetles, as is the case in the other host-specific strains of the disease, however, specific insect vectors have not been identified.

Mortality, primarily occurring in numerous centers scattered over 20,000 to 30,000 acres, has been reported in the Chimney Peak area in southwest Tulare County on land administered by the Bureau of Land Management (Smith 1983b; CFPCR 1991; Merrill et al. 1992).

URBAN FORESTS

Urban forests can be a great economic and aesthetic asset to a community. Healthy trees of all sizes can add to property values, aid energy conservation by providing shade, reduce noise and air pollution, provide wildlife habitat, and provide aesthetic enhancement. Many abiotic conditions can affect the condition of urban forests: air pollution, soil compaction, drought, improper irrigation or incompatible landscape vegetation, construction related injuries, and thermal radiation from pavement, sidewalks and buildings. Following are some of the hosts which have historically or are currently being affected by insects and pathogens.

Elm trees

Elm trees are one of the many trees that have been introduced into the state. An estimated 2.5 million elms have been planted in California (Svihra 1980). Dutch elm disease and elm leaf beetle are two of the most destructive agents affecting

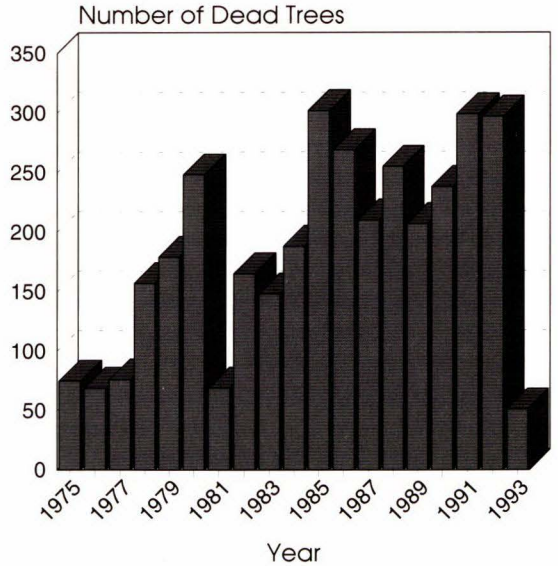


Figure 4-18 -- Number of confirmed dead elm trees by year in counties with a state Dutch elm disease program, 1975-1993.

Figure 4-17 -- Counties with current or sporadic infections of Dutch elm disease on elm trees.

elms in California. Dutch elm disease was first detected in California in 1975. Dendrochronology exams indicated the disease may have been present as early as the 1950s. An eradication effort was conducted against Dutch elm disease from 1975 to 1980, but was changed to a control effort in 1981 (Owen & Lownsbery 1989). Since 1975, the state program designed to detect and remove infected trees has confirmed 3,502 diseased elms in 11 counties (Figure 4-17, 4-18). Most infected trees are European and American elms. Others infected are Siberian and Chinese elms, and Japanese zelkova. The Dutch elm disease program was reduced in the early 1990's, and in 1993 the program was completely eliminated. There is currently no coordinated statewide detection or monitoring program for Dutch elm disease.

All elm species grown in the state may be attacked by elm leaf beetle. The elm leaf beetle was accidentally introduced from Europe into the United States in the 1830's and was first reported in California in the 1920's (Dahlsten et al. 1990). It has one to four generations a year in California depending upon location and weather. The damage is caused by the larvae which feed in the canopy on the lower sides of the leaves. Larval feeding results in skeletonized leaves which turn brown and may drop prematurely. Many elm trees within the urban and residential areas of the state are chemically treated annually to reduce the impacts of elm leaf beetle.

Eucalyptus

Eucalyptus trees are native to Australia but have been widely planted in the tropical and subtropical regions throughout the world. Eucalyptus trees have been planted throughout California, primarily for windbreaks, soil stabilization, fuelwood, and for their attractive leaves and bark. The primary insect affecting eucalyptus in California is the eucalyptus longhorned borer. The blue gum and eucalyptus psyllids also cause extensive damage to eucalyptus trees throughout the state.

The eucalyptus longhorned borer, native to Australia, was first detected in southern California (Orange County) in 1984 and was soon found in several surrounding counties. The current distribution of the eucalyptus longhorned borer in California includes 18 counties (Figure 4-19). The adult borer lays eggs under loose bark of recently cut or fallen branches or trees. The phloem-feeding larvae girdle the cambial layer and tunnel into the wood to pupate. Healthy trees with ample gum (kino) flow are able to defend against the initial larval feeding. Many species of eucalyptus, especially blue gum and manna gum, are susceptible to attack.

Intra- and intercounty transport of borer infested firewood allows for the rapid geographical spread of this insect. Soil and trunk-injected systemic insecticides have provided unacceptable control of eucalyptus longhorned borer.

Cultural practices designed to improve tree health, firewood management, and biological control strategies seem practical for long-term management of this introduced insect. University of California, Riverside, is conducting egg parasite and larvae parasite release trials at several southern California

Figure 4-17 -- Counties with detections of Eucalyptus longhorned borer infesting eucalyptus trees..

areas and also on the Standford University campus in central California.

Multi-hosts

The ash whitefly was identified on ash trees in Los Angeles county in 1988. Since that time it has spread to 47 counties throughout the state (Figure 4-20) and into nearby states. In California it has been found on most varieties of citrus and on apricot, pomegranate, toyon, several species of pears, as well as several species of ash (Gill 1990). Damage is caused by the whitefly attaching itself to the undersides of leaves and sucking the plant juices. Feeding can result in stunting, poor growth, defoliation, reduced yields on commercial crops and sometimes death. There are thought to be two generations a year, however in Southern California there may be more. Like other whiteflies, it secretes a sticky honeydew that promotes the growth of black sooty mold and also attracts ants. Pesticides have proven ineffective due to immediate reinfestation by ash whiteflies from other nearby trees. No natural enemies of the ash whitefly have been found in California, however two imported natural enemies, a tiny stingless wasp and a ladybird beetle, have reduced infestations in many areas throughout the state.

The gypsy moth, both European and Asian strains, has tremendous potential to damage host trees throughout California in both urban and non-urban settings. Many native and introduced ornamental trees in California would be suitable gypsy moth hosts. Currently, the California Department of Food and Agriculture uses a three step strategy throughout the state to prevent the establishment of gypsy moth in California. These are exclusion, detection and eradication. The pest exclusion program is designed to prevent the entry of exotic pests into California. It includes inspection activities at border agricultural inspection stations, airports, seaport terminals and interior terminal inspection points. Pest detection is comprised of trapping and survey programs to detect exotic pests that have escaped the exclusion program. When exotic pest infestations are found and eradication is feasible, an eradication project is initiated.

Since 1989, a total of 77 gypsy moths (all European) have been trapped in California. Subsequent intensive trapping and egg mass surveys in these areas were negative except for a site in Marin County in 1989. This site was chemically treated in the spring of 1990 and no additional gypsy moths have been detected in that area. An additional 31 gypsy moths have been caught in traps placed at quarantine sites. These sites were the destinations of vehicles found infested with gypsy moths at border stations. Viable egg masses or pupal cases were found on 2 of these sites. Figure 4-21 shows the the distribution of gypsy moth finds in California between 1989-1993. Most gypsy moths have been detected in major metropolitan areas and along Interstates 5 and 80. Since 1989, nine gypsy moths have been trapped in forested areas of the state (Mariposa, Tuolumne, Shasta and Nevada counties).

Figure 4-19 -- Counties with detections of ash whitefly.

There are several native and introduced pine species in the urban areas of California. Pine pitch canker has the portential to have a significant impact on these hosts. Pine pitch canker was first detected on Monterey pine near Santa Cruz in 1986. Initial surveys detected the pathogen in four surrounding counties. Most of the infected trees were Monterey pine, however three other pine species were also infected in these areas. The pathogen has since been found infecting twelve pine species in thirteen counties, and one Douglas-fir in Santa Cruz County (Figure 4-1). Most infections are of ornamentally planted and roadside Monterey pine within the central and southern coastal California communities. The disease has been found in several Monterey pine Christmas tree farms in southern California. Only recently (1992) have diseased trees been observed in two of the three native Monterey pine stands in California. Insects are associated with the disease epidemiology. Several twig, cone and bark beetles act as vectors of the pathogen. Moderately to severely infected pines are often killed by pine engraver beetles.■

Figure 4-20 --Distribution of gypsy moth finds in California between 1989-1993.

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APPENDIX A

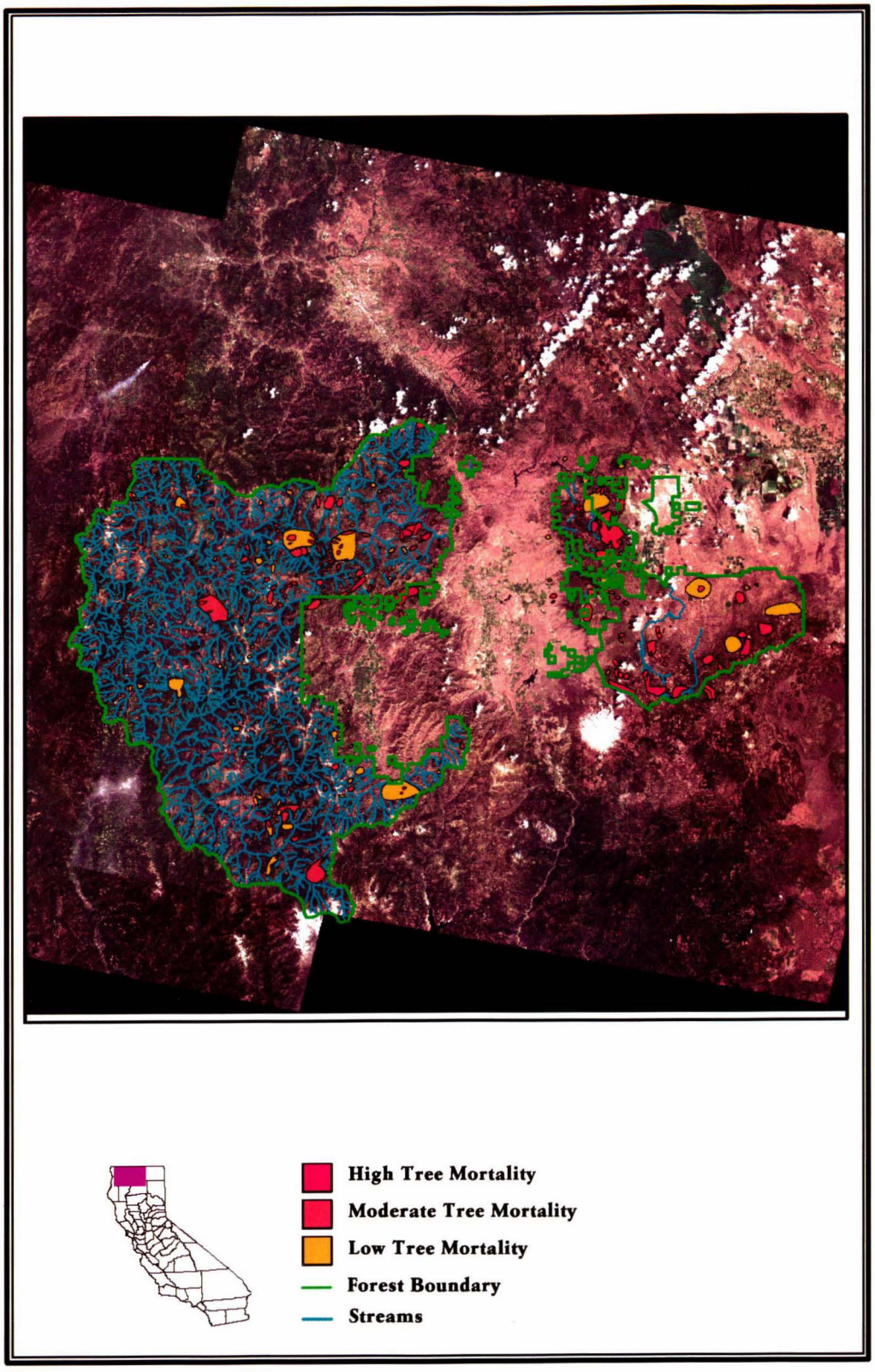

Figure A-1 -- Areas of conifer mortality detected by aerial sketch map survey on the Klamath National Forest, 1993, overlayed on Landsat Theramatic Mapper imagery.

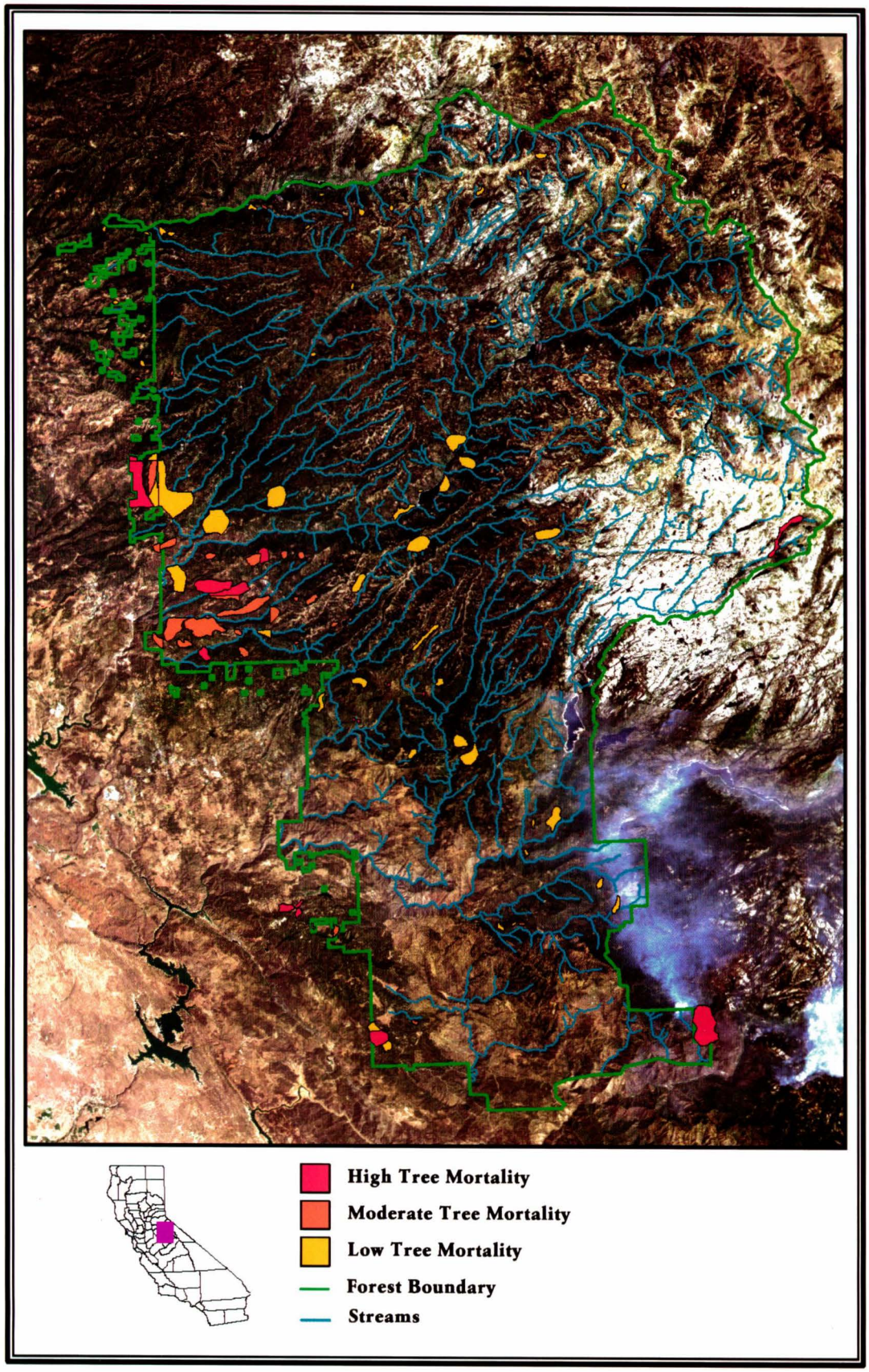

Figure A-2 -- Areas of conifer mortality detected by aerial sketch map survey on the Stanislaus National Forest, 1993, overlayed on Landsat Theramatic Mapper imagery.

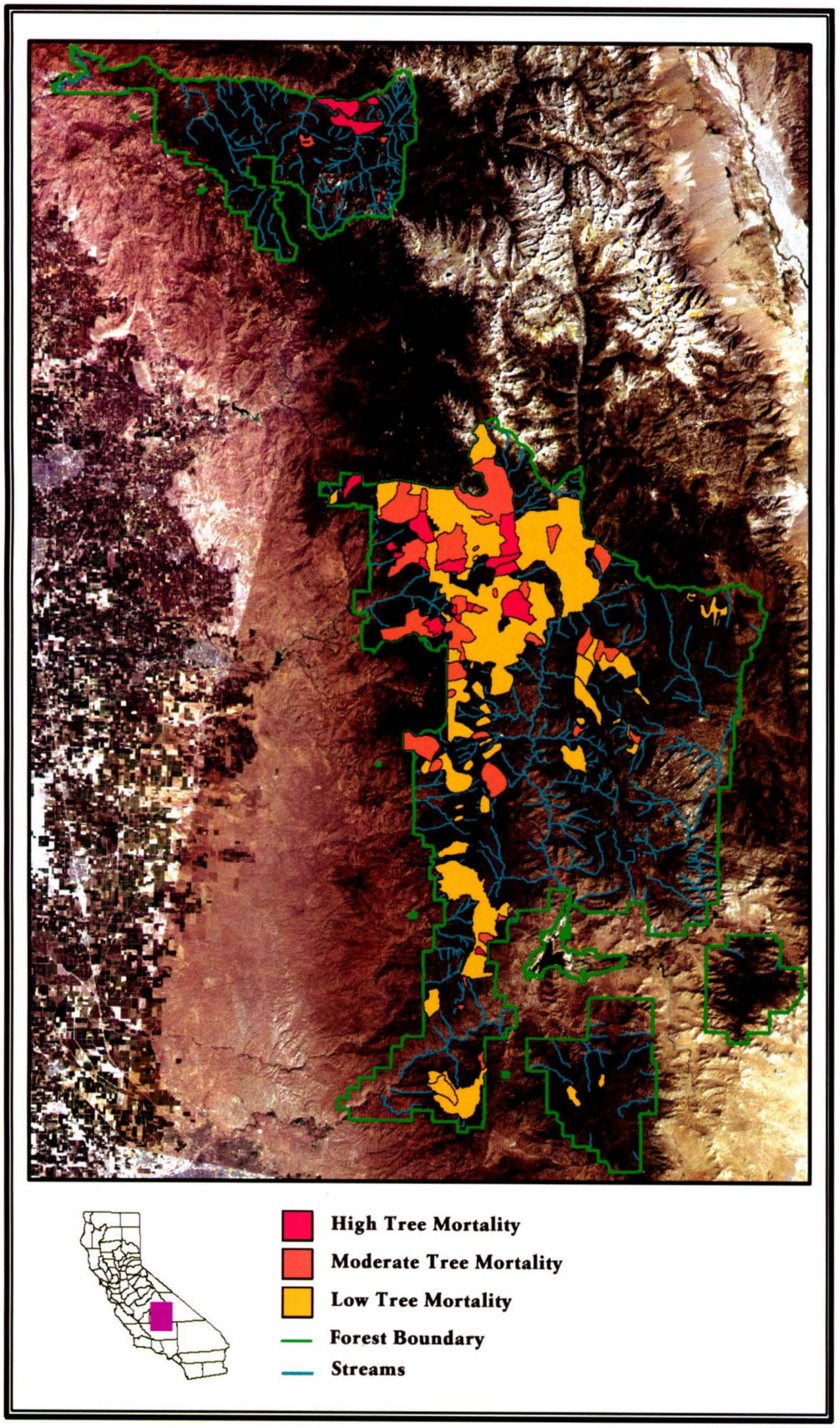

Figure A-3 -- Areas of conifer mortality detected by aerial sketch map survey on the Sequoia National Forest, 1993, overlayed on Landsat Theramatic Mapper imagery.

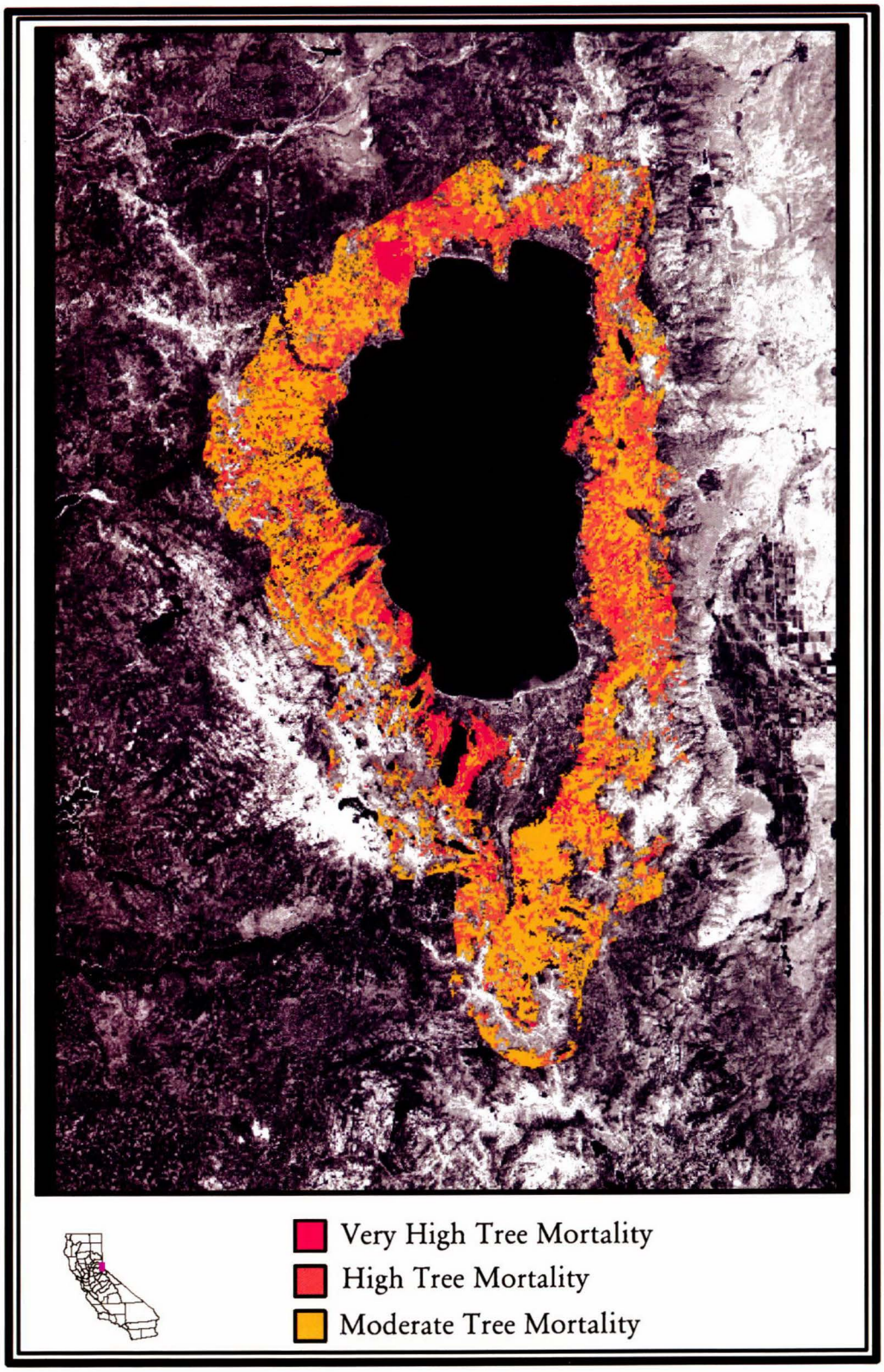

Figure A-4 -- Areas of conifer mortality detected by a canopy reflectance model comparing the Landsat Theramatic Mappter (TM) imagery of 1988 and 1991, Lake Tahoe Basin Management Unit. Conifer mortality is overlayed on Landsat TM imagery.

APPENDIX B

Index of Scientific and Common Names

Scientific and common names of insects, pathogens and trees referenced in this report are listed in alphabetic order by scientific name:

Insects

Scientific Name	Common Name
Agrilus angelicus	Oak twig girdler
Archips argyrospilus	Fruittree leafroller
Asterolecanium minus	Oak pit scale
Chionodes trichostola	Gelechiid leaf skeletonizer
Choristoneura carnana californica	Trinity budworm
Choristoneura conflictana	Large aspen tortrix
Choristoneura lambertiana	Sugar pine tortrix
Choristoneura retiniana	Modoc budworm
Coleotechnites milleri	Lodgepole needleminer
Coleotechnites sp.	Jeffrey pine needleminer
Coloradia pandora	Pandora moth
Ctenarytaina eucalypti	Blue gum psyllid
Ctenarytaina spp.	Eucalyptus psyllid
Dendroctonus brevicomis	Western pine beetle
Dendroctonus jeffreyi	Jeffrey pine beetle
Dendroctonus ponderosae	Mountain pine beetle
Dendroctonus pseudotsugae	Douglas fir beetle
Dendroctonus valens	Red turpentine beetle
Epinota emarginana	Tortricid leaf roller
Epinotia meritana	White fir needleminer
Ips confusus	Pinyon pine engraver beetle
Ips paraconfusus	California 5-spined engraver beetle
Ips spp.	Pine engraver beetle
Leucoma salicis	Satin moth
Lymantria dispar	Gypsy moth
Malacosoma constrictum	Pacific tent caterpillar
Malacosoma spp.	Western tent caterpillar
Melanophila californica	California flatheaded borer
Melanophila drummondi	Fir flatheaded borer
Neodiprion abietis	White fir sawfly
Nuculaspis californica	Black pineleaf scale
Orgyia pseudotsugata	Douglas-fir tussock moth
Phloeosinus spp.	Cedar bark beetles
Phoracantha semipunctata	Eucalyptus longhorned borer
Phryganidia californica	California oak moth
Pseudohylesinus nebulosus	Douglas fir pole beetle
Pseudohylesinus siriceus	Silver fir beetle
Pseudopityophthorus spp.	Oak bark beetle
Scolytus unispinosus	Douglas-fir engraver beetle
Scolytus ventralis	Fir engraver beetle
Siphoninus phillyreae	Ash whitefly
Tetropium abietis	Roundheaded fir borer
Xanthogaleruca luteola	Elm leaf beetle
Zelleria haimbachi	Pine needle sheathminer

Pathogens

Scientific Name	Common Name
Anthracnose sp.	
Arceuthobium abietinum f. sp. *concoloris*	White fir dwarf mistletoe
Arceuthobium abietinum f. sp. *magnificae*	Red fir dwarf mistletoe
Arceuthobium americanum	Lodgepole pine dwarf mistletoe
Arceuthobium californicum	Sugar pine dwarf mistletoe
Arceuthobium campylopodum	Western dwarf mistletoe
Arceuthobium cyanocarpum	Limber pine dwarf mistletoe
Arceuthobium divaricatum	Pinyon dwarf mistletoe
Arceuthobium douglasii	Douglas-fir dwarf mistletoe
Arceuthobium littorum	Coastal dwarf mistletoe
Arceuthobium monticola	White pine dwarf mistletoe
Arceuthobium occidentale	Grey pine dwarf mistletoe
Arceuthobium siskiyouense	Knobcone pine dwarf mistletoe
Arceuthobium tsugense	Hemlock dwarf mistletoe
Armillaria ostoyae	Armillaria root disease
Armillaria mellea	Oak root fungus
Botryosphaeria spp.	Botryosphaeria canker
Cronartium ribicola	White pine blister rust
Cryptocline cinerescens	Oak anthacnose
Cylindrosporium spp.	
Cytospora abietis	Cytospora canker
Diplodia quercina	Oak canker
Discula quercina	Oak anthracnose
Fusarium subglutinans f. sp. *pini*	Pitch canker
Fusicoccum aesculi	Madrone canker
Heterobasidion annosum	Annosus root disease
Inonotus andersonii	Oak canker rot
Leptographium wageneri	Black stain root disease
Lophodermella arcuata	Sugar pine needle cast
Mycosphaerella fraxinicola	
Ophiostoma ulmi	Dutch elm disease
Phoradendron bolleanum ssp. *pauciflorum*	White fir true mistletoe
Phytophthora lateralis	Port Orford cedar root disease
Phytophthora spp.	Water mold fungi
Septoria spp.	

Trees

Scientific Name	Common Name
Abies concolor	White fir
Abies grandis	Grand fir
Abies magnifica	Red fir
Acer macrophyllum	Big-leaf maple
Alnus rhombifolia	White alder
Alnus rubra	Red alder
Arbutus menziessi	Madrone
Cercidium floridum	Palo Verde
Chamaecyparis lawsoniana	Port Orford cedar
Cornus nuttallii	Dogwood
Cupressus macrocarpa	Monterey cypress

Juniperus californica	California juniper
Juniperus occidentalis	Western juniper
Juniperus osteosperma	Utah juniper
Libocedrus decurrens	Incense cedar
Lithocarpus densiflorus	Tanoak
Picea sitchensis	Sitka spruce
Pinus albicaulis	Whitebark pine
Pinus attenuata	Knobcone pine
Pinus aristata	Bristlecone pine
Pinus balfourniana	Foxtail pine
Pinus contorta var. *murrayana*	Lodgepole pine
Pinus coulteri	Coulter pine
Pinus flexilis	Limber pine
Pinus jeffreyi	Jeffrey pine
Pinus lambertiana	Sugar pine
Pinus monophylla	Singleleaf pinyon pine
Pinus monitocola	Western white pine
Pinus muricata	Bishop pine
Pinus ponderosa	Ponderosa pine
Pinus quadrifolia	Parry pinyon pine
Pinus radiata	Monterey pine
Pinus sabiniana	Grey pine
Pinus torreyana	Torrey pine
Pinus washoensis	Washoe pine
Populus fremontii	Fremont cottonwood
Populus tremuloides	Quaking aspen
Populus trichocarpa	Black cottonwood
Pseudotsuga menziesii	Douglas-fir
Pseudotsuga macrocarpa	Big-cone Douglas-fir
Quercus agrifolia	Coast live oak
Quercus chrysolepis	Canyon live oak
Quercus douglasii	Blue oak
Quercus engelmannii	Engelmnn oak
Quercus garryana	Oregon white oak
Quercus kelloggii	Black oak
Quercus lobata	Valley oak
Quercus tomentella	Island oak
Quercus wislizenii	Interior live oak
Salix goodingii	Willow
Sequoia sempervirens	Coast redwood
Sequoiadendron giganteum	Giant sequoia
Tamarix	Tamarisk
Taxus brevifolia	Pacific yew
Tsuga mertensiana	Mountain hemlock
Tsuga heterophylla	Western hemlock
Ulmus americana	American elm
Ulmus procera	English elm
Ulmus pumila	Siberian elm
Ulmus parvifolia	Chinese elm
Yucca brevifolia	Joshua tree
Zelkova serrata	Japanese zelkova

Shrubs

Scientific Name	Common Name
Arctostaphylos	Bigberry manzanita
Arctostaphylos sp.	Manzanita
Arctostaphylos glauca	Eastwood manzanita
Artemisia sp.	Sagebrush
Atriplex sp.	Saltbush
Ceanothus sp.	Ceanothus
Ceanothus crassifolius	Hoaryleaf ceanothus
Ceanothus megacarpus	
Ceanothus spinosus	Spiny ceanothus
Ceanothus leucodermis	Chaparral whitethorn
Coleogyne ramosissima	Blackbush
Heteromeles arbutifolia	Toyon
Ribes sp.	Currant
Larrea sp.	Creosote
Sarcobatus verniculatus	Greasewood

Animals

Scientific Name	Common Name
Aplodontia rufa	Mountain beaver
Castor canadensis	Beaver
Cervus elaphus	Elk
Erethizon dorsatum	Porcupine
Lepus sp.	Hares
Microtus sp.	Voles
Neotoma sp.	Woodrat
Odocoileus hemionus	Deer
Sciurus sp.	Tree squirrels
Sylvilagus sp.	Rabbits
Thomomys sp.	Pocket gopher
Tamiasciura douglasii	Douglas' squirrel
Ursus americanus	Black bear

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